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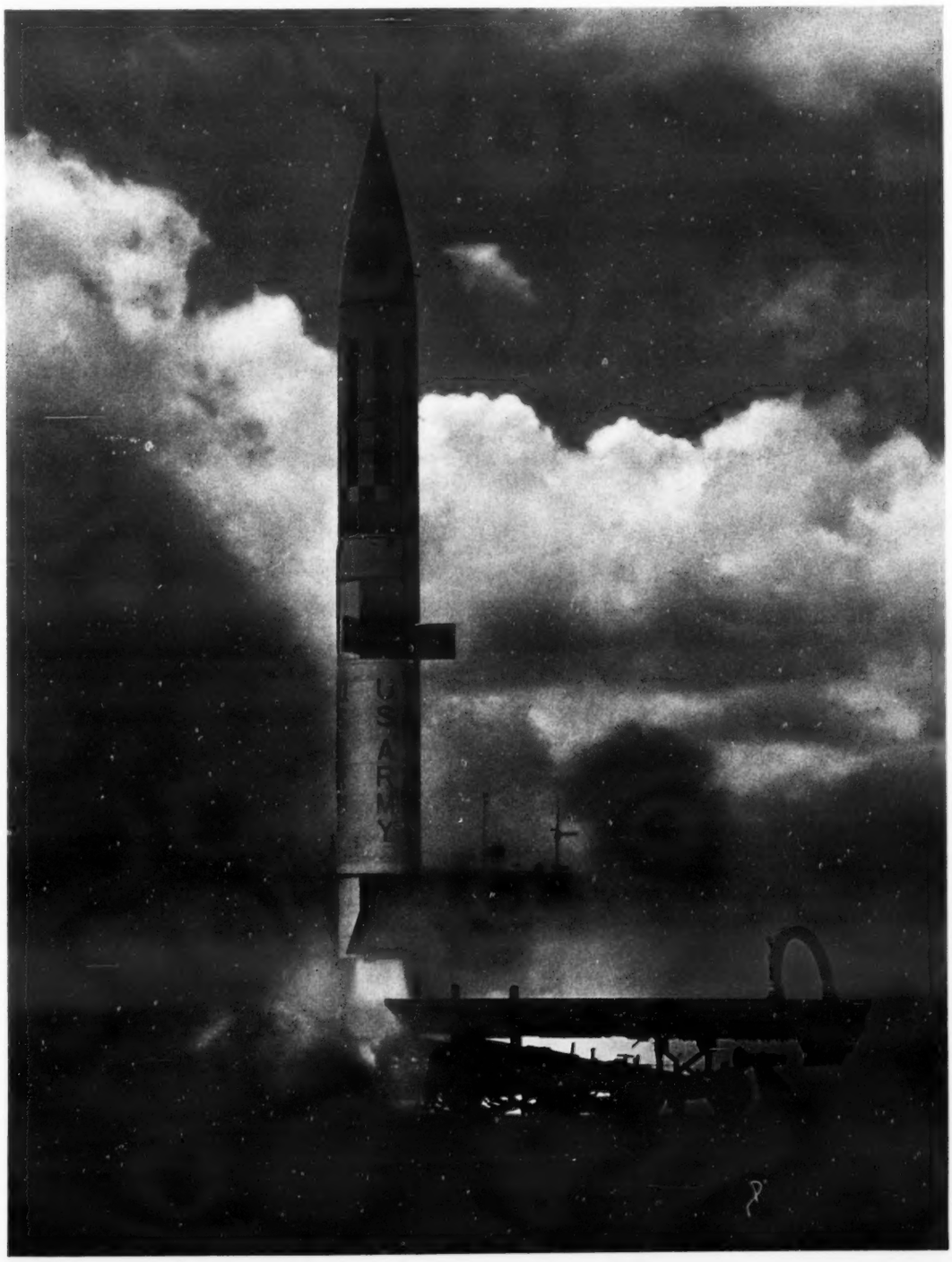

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TARAN System

Autonetics Story

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Volume XVI

INTERAVIA

March 1961

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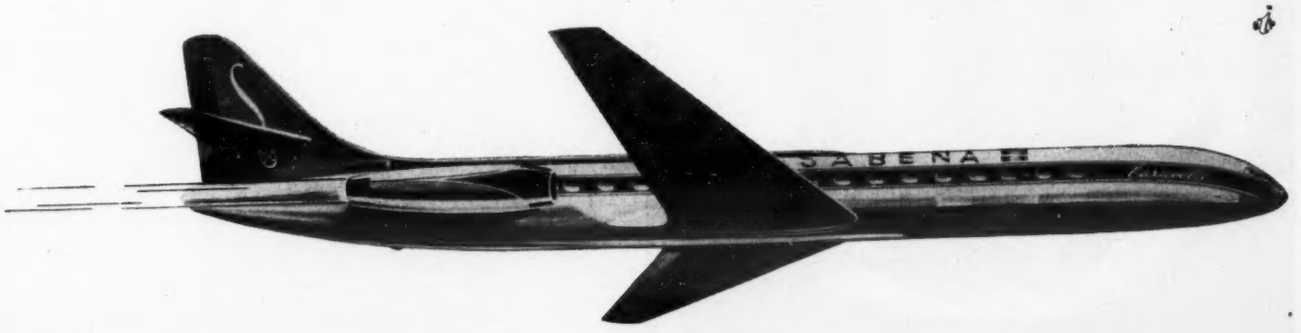
Front Cover: U.S. Army *Pershing* rocket being fired from a standard launcher



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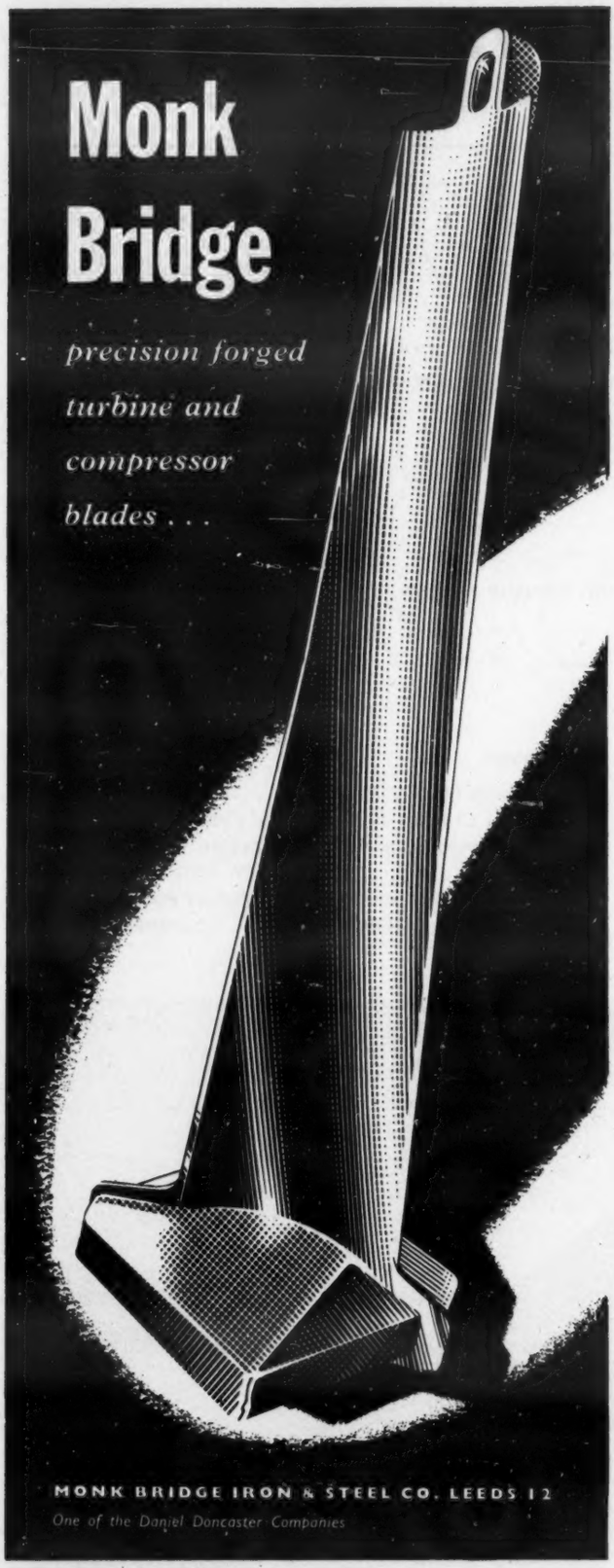

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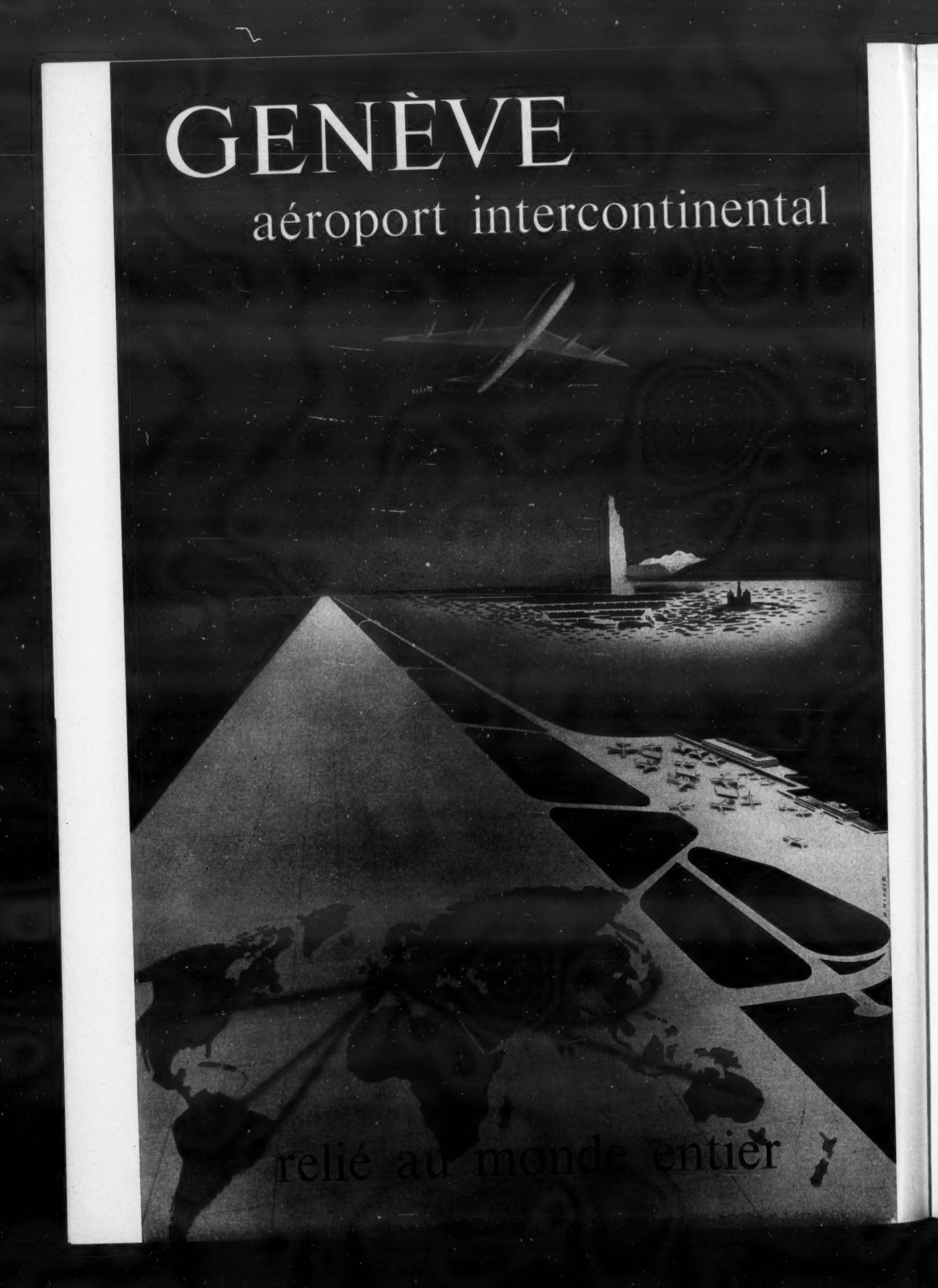
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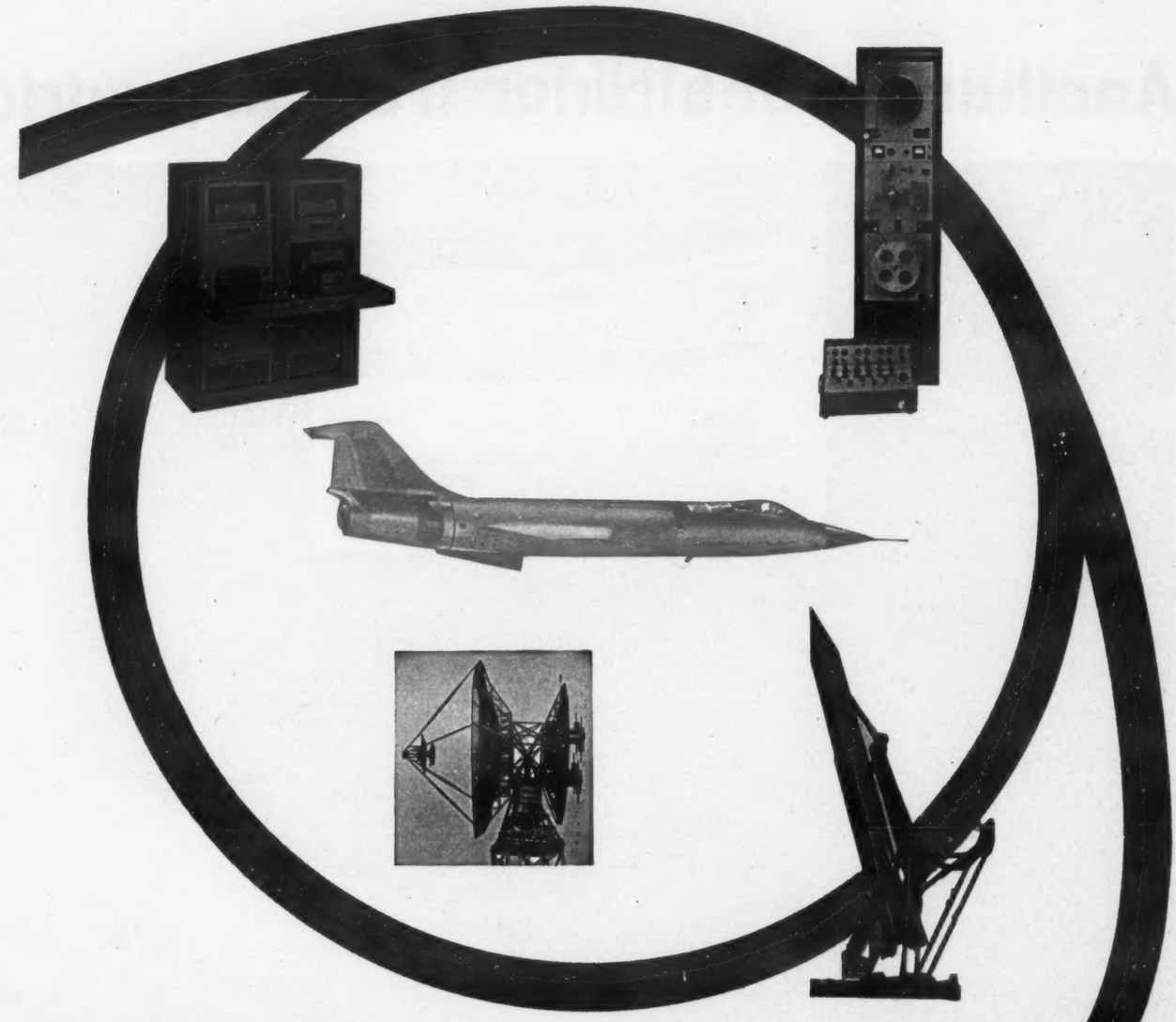

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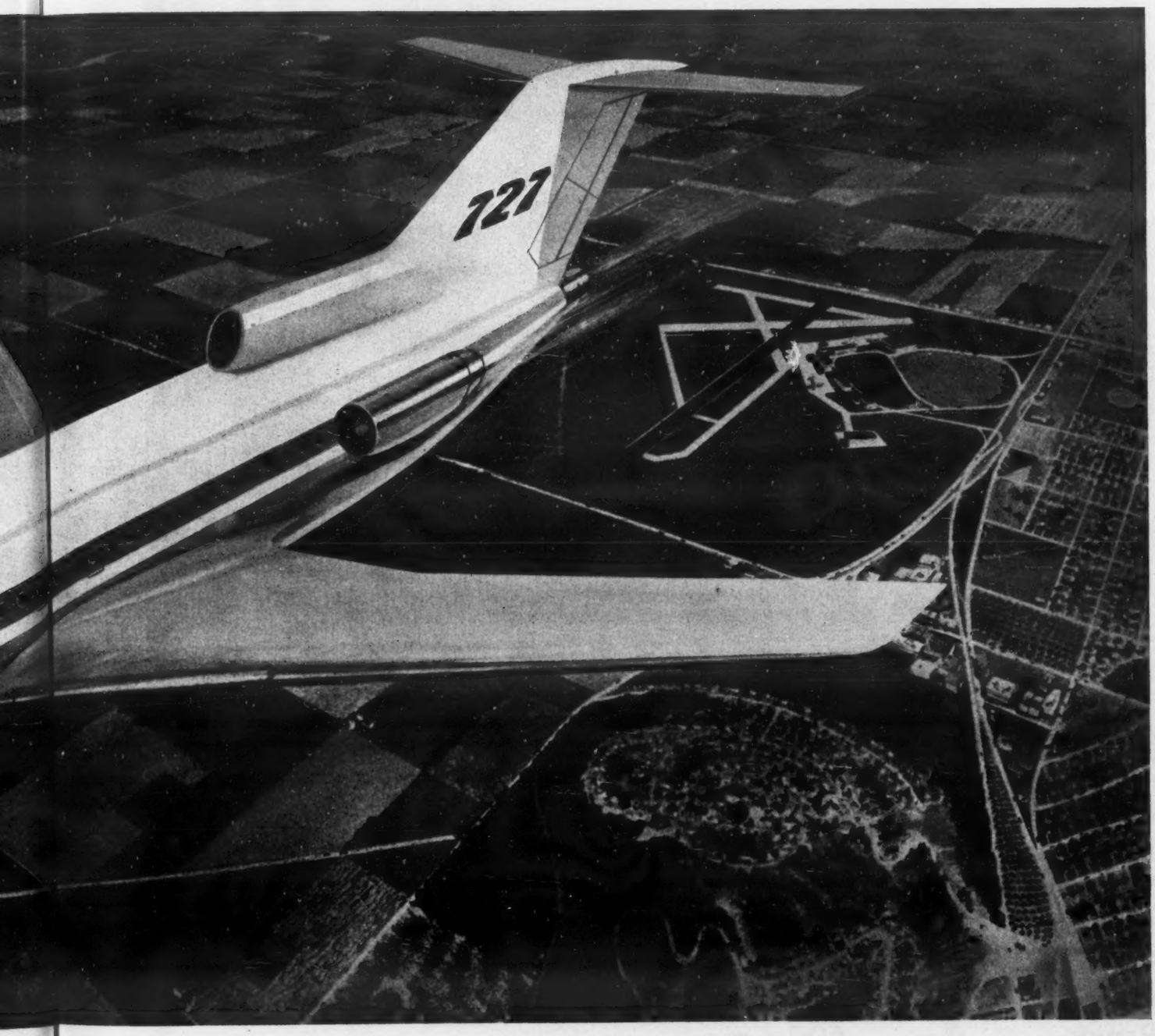

components proved in the 707 and 720. It also has the same cabin width, permitting 4-, 5- or 6-abreast seating to meet competitive requirements, whether for "big-jet" luxury or for high-density service. The 727 is designed to operate from 5,000-foot runways with full payload, and to serve economically on routes from 150 to 1,700 miles. It offers the added profit potential of 850 cubic feet of cargo space. Speed is 550 to 600 mph.

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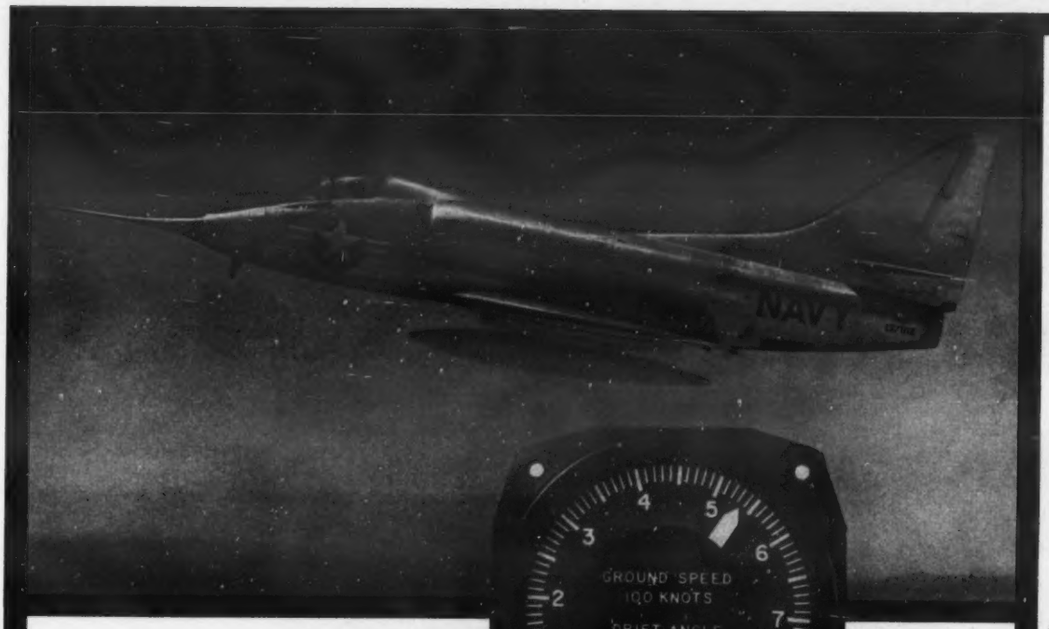

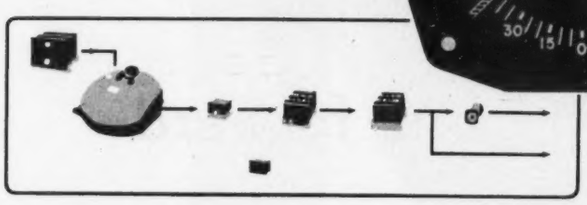

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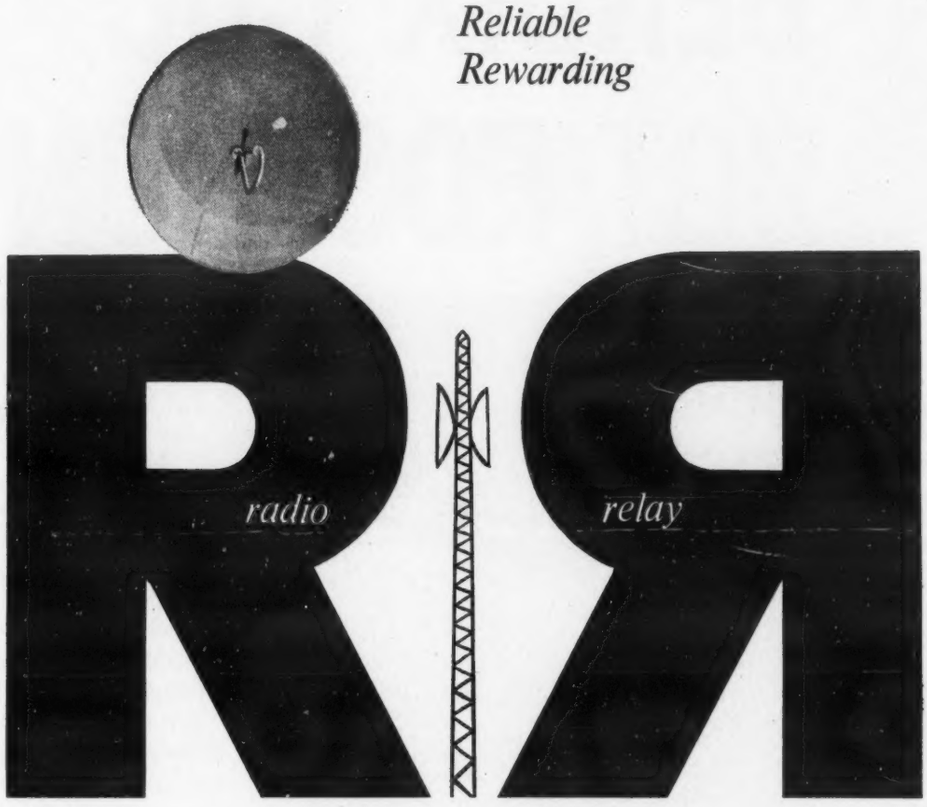

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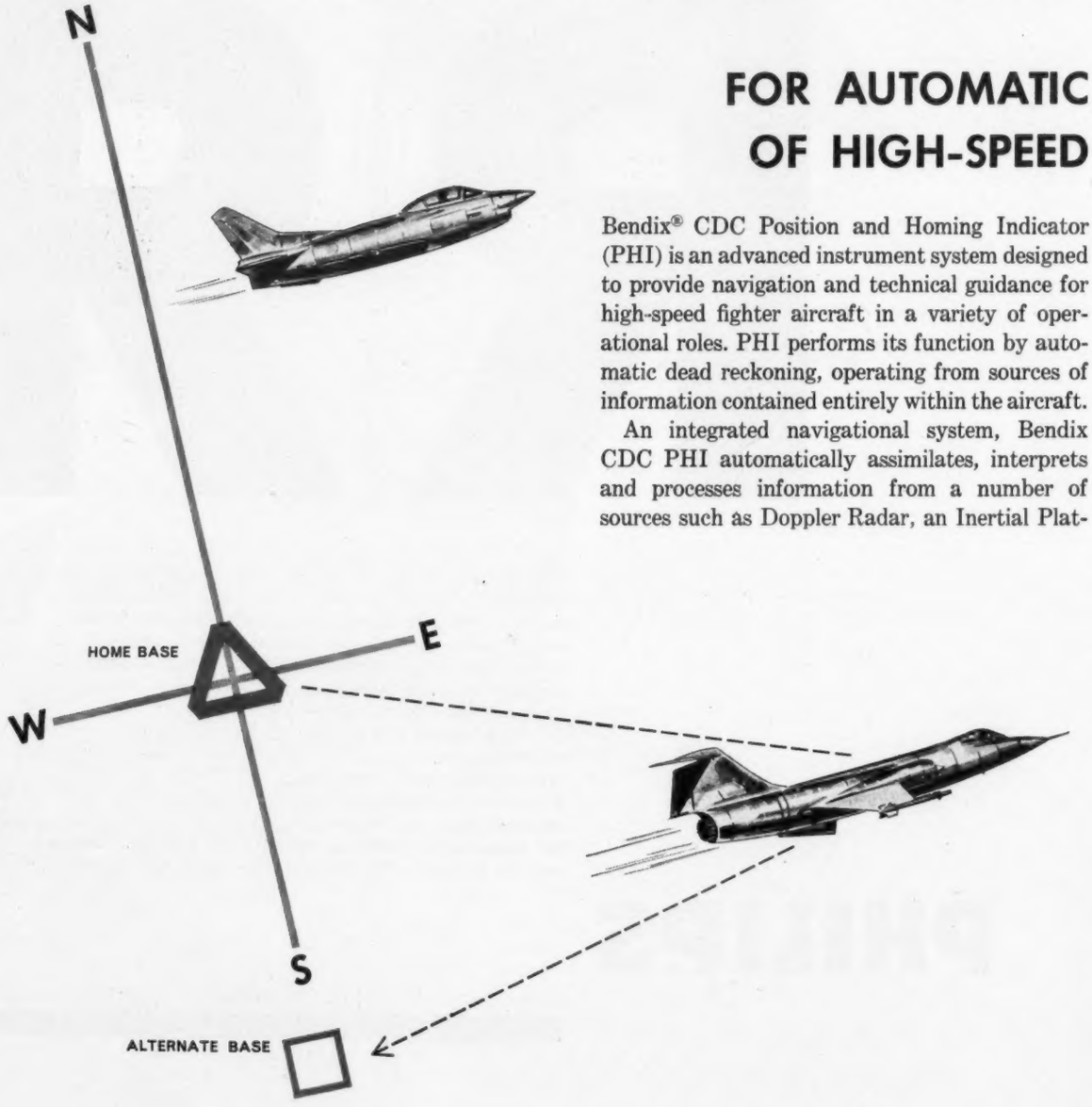

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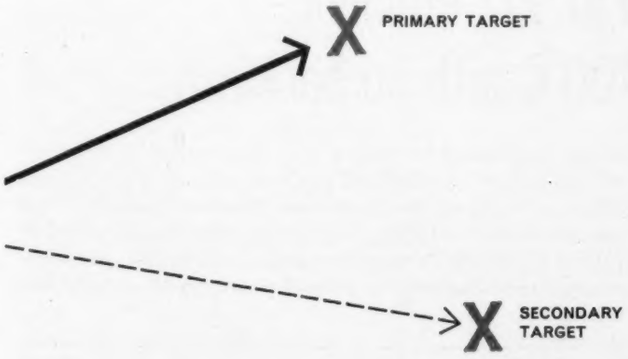

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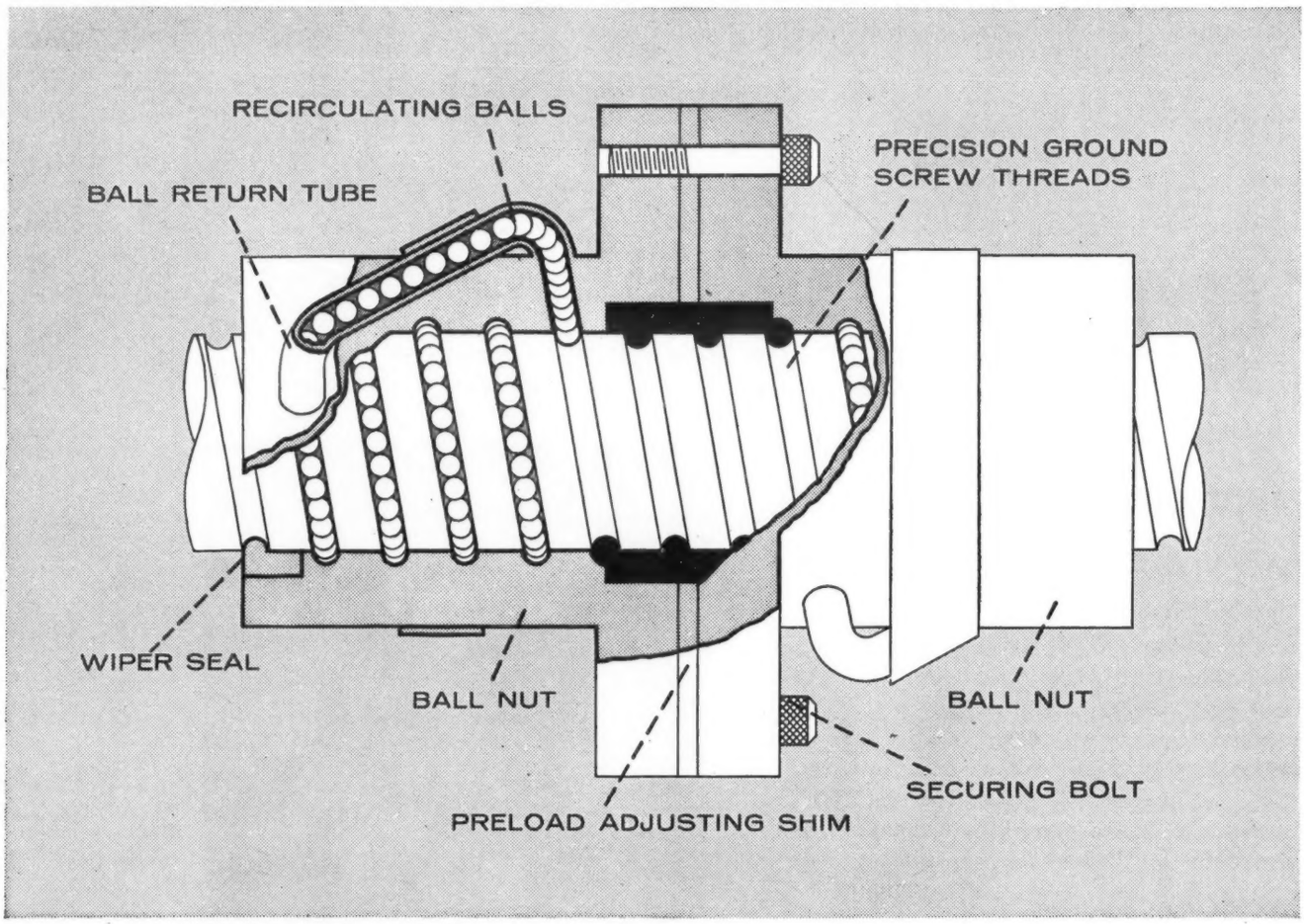

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INTERAVIA AIR LETTER reports...*

Air Transportation

Max Hymans, Honorary President of Air France, died at his home in Paris on March 7th, at the age of 61. Hymans was the man who, after World War II, reorganized French civil aviation, built the national flag carrier Air France to its present position of importance, played an important role in the formation of ICAO, and worked untiringly for better understanding in the international civil aviation field.

Born in Paris in 1900, Hymans began his career as a lawyer and then entered the political field, becoming a Deputy in the National Assembly in 1928 and later serving as Secretary for Trade and Industry and Secretary of State for Finance. In World War II he fought as an Artillery Captain and then with the French Resistance before escaping to England to join the Free French Forces. In 1944 he headed the French delegation to the Chicago conference, was appointed Secretary General for civil and commercial aviation in 1945 and took over the Presidency of Air France in 1948. He also served a term as IATA President in 1954-55.

Hymans' death is a great loss not only to European civil aviation but also in the international field, but he has clearly left his mark on the developments of the last two decades.

●

Pan American World Airways has given Boeing Airplane Co. an order for five 707 320Bs and has taken an option on a further five. First delivery is scheduled for March 1962. The 320B model is powered by four P&W JT3D-3 turbofan engines, developing 18,000 lb thrust each, giving a 15 percent improvement on current model 320 performance, and will have full span leading edge flaps and more efficient trailing edge flaps for improved landing and take-off performance. Maximum taxi weight 317,000 lb. Maximum flight weight 312,000 lb. Maximum permitted payload 56,900 lb.

●

American Airlines will introduce fan-engined Boeing jets (720Bs and re-engined 707-123s, with four water-injection P&W JT3D-1s of 18,000 lb thrust each) into service on March 12th, with daily roundtrip service New York-Los Angeles, New York-Chicago and Chicago-Mexico City. (American is referring to all turbofan jets—123Bs, 720Bs and Convair 990s—as *"Astrojets,"* and is using their introduction into service to promote "Stage II of the Jet Age").

American has one 707-120B on order as the prototype, and this aircraft has been flying at Seattle since June 1960. Three of the carrier's 707-123s have been withdrawn from service and are at Seattle for conversion to the B-model; the other 20 and the ten 720s already delivered will be rotated to Seattle for completion of the modification by January 1962. With a further fifteen 720Bs on order, American will thus eventually have a fleet of 49 fan-engined Boeing jets (24 x 123B, and 25 x 720B—two of the original batch of 707-123s having been destroyed in crashes). The 123 modification includes new struts and reworking the wing centre section, and the JT3D fan units will give a cruising speed of 612 m.p.h. and a 20-25 percent fuel saving. Boeing hoped to get certification of both the 120B and 720B by the end of February.

●

Argentine operator, Transatlántica Argentina, is negotiating with the Israeli authorities for a permit to extend its once-weekly Lockheed L-1649A service Buenos Aires-Recife-Lisbon-Geneva to Tel Aviv via Milan. Reports from Tel Aviv indicate that Israel is agreeable, providing that the Argentine authorities sign an air agreement. Meanwhile, Israel will probably authorize the carrier to operate a certain number of charter flights to Tel Aviv.

●

Papeete International Airport will be opened to jet traffic on May 1st, and TAI's Paris-India-South Pacific-Los Angeles service will be opened with Douglas DC-8s from that date. TAI is due to take delivery of its third DC-8 series 30 in April.

●

Japan Air Lines has taken a firm decision to purchase two additional Convair 880-22Ms for service on the south-east Asia route network. JAL has three Convair 880-22Ms on order for delivery in May and June this year, and has obtained informal approval from various government agencies for the new order. Price is $4,250,000 per aircraft.

●

Air-India International will include Prague as a regular stop on Boeing 707 services to and from New York via London from May 3rd. Trans-Atlantic jet service will be stepped up to five flights a week India-Middle East-Europe-New York, with eastbound departures daily except Monday and Tuesday.

●

South African Airways' Boeing 707 services on the Johannesburg-London route will call at Paris once a week, effective April 4th. The route will be Johannesburg-Brazzaville-Rome-Paris-London. SAA last served Paris three years ago with a Constellation service which was withdrawn because of lack of traffic.

●

The revised Scandinavian-West German air agreement, now extended to November 1964, cuts SAS transit rights in West Germany from 25 to 16 landings a week. SAS income will be cut by 10-20 million crowns ($ 1.9-3.8m.) per year.

●

BOAC will open a new route to South America on April 11th with twice-weekly Boeing 707-436 service London-New York-Nassau-Lima. Tuesday and Thursday services will depart London 11.15 BST, and elapsed time for the 7,000-mile flight will be 18 hours 20 minutes; eastbound elapsed time 17 hours 15 minutes.

Interflug, the foreign operating company for East German Lufthansa, is negotiating for a permit to operate regular scheduled service between Vienna and Berlin-Schönefeld, with Austrian Airlines receiving parallel rights from East Germany. Official negotiations are difficult as Austria does not have diplomatic relations with the East German Government.

Industry

USIA6, the French Aircraft Industries Association, announces that aeronautical export orders in 1960 totalled NF 1,142,588,643 ($228.5m.), an increase of almost 250 percent on the 1959 total of 45,000 million old francs ($90m.). The 1960 total included: complete aircraft and airframes - NF 736,221,606 ($147.2m.); helicopters - NF 73,858,860 ($14.8m.); engines - NF 81,134,557 ($16.2m.); missiles - NF 145,137,064 ($29.0m.); equipment - NF 72,500,398 ($14.5m.). Sixty percent of the total was for civil orders and the balance for military, a ratio largely accounted for by the success of the *Caravelle* and *Alouette.*

●

Max Holste is working on a military version of the *Super Broussard* with an eye to French procurement of a medium-range military transport. The aircraft would be powered by two 1,100 h.p. *Bastan Vs;* all-up weight about 9.4 tons; payload 1.5 tons for ranges of up to 810 n.m. (1,500 km); cruising speed about 190 knots. First mention of the Dassault *Super-Communauté* in connection with this programme has been made. No details have yet been published (the Breguet 945 is the third competitor in this programme).

●

Saab Aircraft Co. has received a major French Government contract to supply Type BT9F toss-tomb computers to equip the carrier-based Dassault *Etendard IV.* The Swedish bomb sight was selected in competition with other manufacturers' equipment after extensive trials in France. The BT9 is manufactured by Saab's Jönköping division and is developed from a bomb sight in service with the Swedish Air Force at the beginning of World War II. The U.S. Government purchased a quantity of an earlier version in which some of the calculations are performed mechanically. Saab is negotiating BT9 computer sales with other nations.

●

BOAC is now reportedly considering switching its order for 35 VC.10s and ten Super VC.10s to procure only 15 VC.10s for African and Far East routes and 30 of the modified Super VC.10s (170 passengers instead of 180-200). This would have the effect of bringing the new Super VC.10 version onto the production line at the 16th aircraft to give the British carrier a competitive aircraft for North Atlantic service by 1964, a year earlier than originally scheduled.

●

A Vickers Vanguard destined for Trans-Canada Air Lines will arrive at Johannesburg-Jan Smuts Airport on April 1st for three weeks' tropical and high-altitude trials.

●

Early Caravelle I and IA models delivered to SAS and Air France in the spring of 1959 have logged between 3,000 and 4,000 flight hours in 2,500-3,000 flights. Sud-Aviation points out that this utilization rate would give the aircraft 15,000 flights in an expected life of 10 years. The company's test fuselage has been subjected to 100,000 simulated flights in the tank at Etablissement Aéronautique de Toulouse, indicating a safety factor of 6 in relation to the above utilization figures.

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* Interavia Air Letter is a daily international news digest published in English, French ("Courrier Aérien") and German ("Luft-Post"). All rights reserved.

The Associazione Industrie Aeromissilistiche (AIA=Aerospace Industries Association) has set up a committee to coordinate Italian Lockheed F-104G production within the framework of the European programme.

●

Officine Aeronavali SpA at the Venice Lido is converting twin-engine Curtiss C.46 and Douglas C.47 for service with the United Nations in the Congo. U.N. has purchased the aircraft from private companies.

●

Canadian Westinghouse's Electronics Division has delivered the first NASARR (North American Search and Ranging Radar) system for the CF-104 to the RCAF. Canadian Westinghouse has an approximately $20 million Department of Defence Production contract for the equipment awarded in October 1959, and is also building NASARR for Japanese and West German F-104s under sub-contract from North American's Autonetics Division as part of the U.S.-Canadian defence production sharing programme.

●

Kaman Aircraft and Grumman Aircraft Engineering have joined forces in the U.S. Army's light observation helicopter design competition, which is expected to lead to one of the largest aircraft contracts to be awarded by the Defense Department in 1961. Kaman will be prime contractor and weapons system manager.

●

Northrop Corporation's Nortronics Division has received a $2,476,839 letter contract for follow-on production of launchers for the U.S. Army *Hawk* missile. This is the first increment of fiscal 1961 funding which will total over $4,953,679. Northrop has been engaged in design and production on the *Hawk* project since mid-1954 and is now a major participant in the NATO *Hawk* programme for which initial launcher and loader units and major portions of the missile airframe are being provided.

Military Affairs

The U.K.'s 1961 White Paper on Defence for 1961 shows defence estimates for the 1961-62 year totalling £1,655.6 million ($4,663.7m.), an increase of £39.27 million ($110m.) on 1960-61. This represents 7.2 percent of gross national product and just over 25 percent of all government expenditure. A further £18.6 million ($52m.) will be provided by Civil Departments for defence expenditure, an increase of £3.24 million ($9m.) on the 1960-61 figure under this heading. The 1960-61 estimate included £12 million ($33.6m.) in support costs from West Germany which are no longer forthcoming, and the true overall increase in 1961-62 defence programme costs is therefore £51.27 million ($143.6m.).

The breakdown between government departments for 1961-62 is as follows (all figures in £ millions):

	1961-62	1960-61
Admiralty	413.20	397.50
War Office	506.90	487.45
Air Ministry	526.67	529.46
Ministry of Aviation	190.20	185.35
Ministry of Defence	18.63	16.57
Total	£1,655.6	£1,616.33

The Swedish Air Force has now confirmed its intention to introduce the Hughes *Falcon* air-to-air missile to equip later versions of the *Draken*. Discussions have been in hand for some time with Hughes Aircraft and the USAF; the Swedish Air Force has now completed negotiations and technical investigations, and a final agreement is expected shortly. This will include licence production by Saab Aircraft Company in Sweden, but a limited number of missiles and certain equipment will be purchased from the United States for testing and adapting to Swedish conditions.

The Swedish-U.S. agreement covers purchase of the basic design for both the radar and infra-red homing versions of the *Falcon*, both with conventional warheads. The radar version has all-weather and all-altitude (except very low) capability; the infra-red version can be operated at all altitudes but not in rain and heavy cloud conditions, and has a high anti-jamming capability. The aircraft fire control system and *Falcon* represent an integrated weapon system directly adapted to STRIL 60, Sweden's semi-automatic air defence control system.

●

The U.S. Marine Corps' choice of a large utility combat-transport helicopter has finally fallen on the Vertol 107M (M=Marine). The West German Government has been awaiting the U.S. decision before making a similar choice, and the Vertol 107 is now expected to be ordered in quantity for the West German Armed Forces.

●

The first six North American T-39B *Sabreliners* for U.S. Air Force Tactical Air Command (delivery one per month) are being fitted with NASARR and a Doppler navigation system for training fighter pilots. Following delivery of the six "B" aircraft, the Air Force will begin receiving the "A" version, without the radar and navigation training system.

Five production model-A *Sabreliners* are undergoing various flight test programmes by the Air Force, the FAA and North American. One T-39A is undergoing cold-weather tests in Alaska.

New Aircraft

Douglas Aircraft Company is working on a number of projects for small touring aircraft and is undertaking an extensive market analysis for aircraft of this category. De Havilland is also working on two projects of this class, the DH.125 and DH.126, and Israel Aircraft Industries (Bedek) is developing a business aircraft, the B.101. An enthusiastic advocate of the development of a fast jet touring aircraft is Lear, Inc., whose SAAC.23—manufactured by the Swiss-American Aircraft Corporation—is already well under way.

●

The Super-Caravelle, a joint Sud Aviation and Générale Aéronautique Marcel Dassault project, will have an all-up weight of 65 to 75 tons, will be powered by four (unspecified) jet engines and will have a 70 to 80 passenger layout. Cruising speed will be around Mach 2.2, with conventional materials being used for the airframe and current manufacturing processes being retained. The airframe life is estimated at about 30,000 flight hours. Nord-Aviation some time ago received a study contract for a Mach 3 medium-range airliner with a view to obtaining a basis for comparison between a Mach 2.2 aircraft type and an all-steel Mach 3 type. At the same time, SNECMA is developing engines for this range of application, while Nord-Aviation is carrying out special research into jet pipes for such engines. In addition, Nord-Aviation is carrying out design studies for a *Caravelle Junior* (formerly known as *Bébé-Caravelle*), for 40 to 50 passengers. This would in all probability be powered by Pratt & Whitney JTF10 turbofan jets of 8,800 lb thrust, manufactured under licence by SNECMA.

Representatives of Sud Aviation and Boeing are discussing the design of nacelles for the JT8D-1 jet engine (14,000 lb thrust) which will power both the Boeing 727 and the *Caravelle 10*. The main characteristics of the latter aircraft are as follows: Take-off weight 103,300 lb; maximum weight equipped 37.5 tons; maximum cruising speed 455 knots; range 1,850 n.m. with 17,600 lb payload and 7,610 lb reserves, or 2,100 n.m. with payload reduced to 14,180 lb, i.e., 61 passengers; take-off distance at maximum weight 6,660 ft; landing distance 4,460 ft at 89,100 lb landing weight. The delivery date for the first *Caravelle 10s* is quoted as October, 1963.

Astronautics

Argentine scientists launched a research rocket, designated *Centaurus*, on February 2nd. The experiment was carried out on the Pampa de Achala range in Córdoba province. Argentine aviation circles say that the rocket nose and instrumentation, which were carried to a height of about 12 miles, were recovered.

●

Space Vehicle 4 (Sputnik 7) was successfully launched on February 4th, according to a communiqué from the Soviet news agency Tass. It is circling the earth in 89.8 minutes; its orbit has a perigee of 138.9 miles, an apogee of 203.6 miles and an inclination of 64°57'. These figures are more or less those planned. *Space Vehicle 4*, which weighs 14,293 lb, is so far the largest space probe to be placed in orbit, being about 4,400 lb heavier than its predecessor. This figure applies only to the weight of the satellite and not to that of the final stage. Professor L. I. Sedov, Chairman of the Space Commission of the Soviet Academy of Sciences, has told representatives of *Pravda* that *Space Vehicle 4* does not contain a man, thus disproving the many conjectures that a Soviet astronaut might be aboard the satellite. Sedov also stated that the satellite contained neither special equipment for scientific measurements nor recovery equipment. The main purpose of the experiment, he said, was to obtain information to serve for the launching of further heavy satellites.

●

Another heavy Soviet satellite was launched on February 12th. From the vehicle, which went into earth orbit according to plan, a 1,420 lb probe was launched in the direction of Venus. The probe is carrying photographic equipment which will attempt to transmit photographs of Venus back to observation stations on the earth. Further tasks are the collection of trajectory data, and space telecommunications. The Venus probe was about 1,174,000 miles away from the earth on February 17th, its speed at that time being 8,770 m.p.h. Instruments and transmitter were operating normally. The temperature inside the vehicle is 83°F, the air pressure 35.4 in. of mercury. The probe is expected to reach the vicinity of Venus in the second half of May.

Photo credits: Front cover: The Martin Co.; pp. 299-300: manufacturers (3), USAF (2), Evening Standard (1); pp. 301-307: USAF (7), U.S. Army (4), Interavia drawing (1), manufacturers (16); pp. 308-312: manufacturers (12), USAF (2); pp. 312-314: manufacturers (5); pp. 327-330: manufacturers (9), USAF (1), U.S. Navy (1); p. 331: manufacturers (1); pp. 332-334: manufacturers (2), Interavia files (6); pp. 351-353: manufacturers (2), U.S. Army (6), U.S. Navy (1), Levy (1), Interavia (2); pp. 354-355: manufacturers (6); pp. 356-359: manufacturers (11), Interavia drawing (1), U.S. Dept. of Defense (1); pp. 360-363: manufacturers (15); pp. 364-366: Anderson & Cole (1), Cederholm Foto (1), manufacturers (9); pp. 371-372: manufacturers (9), Interavia drawing (1); pp. 373-375: manufacturers (8); pp. 376-378: manufacturers (1); p. 383: author (1); pp. 384-386: CSF (1), author (7).

"It is believed that no other single aircraft in the world can match the performance of the TSR 2..."

The Right Hon Harold Watkinson, MP, British Minister of Defence, speaking at Weybridge, on Friday, 7th October 1960

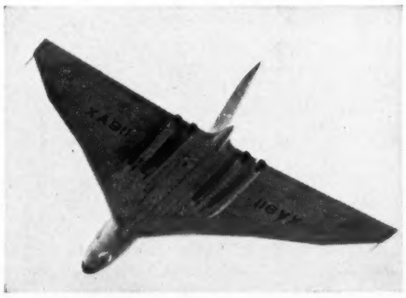
...AND BRISTOL SIDDELEY SUPPLY THE POWER

British Aircraft Corporation have recently received an order from the Ministry of Aviation for a number of TSR 2's. One of the most advanced military aircraft ever to be designed, the TSR 2 will be used in tactical strike and reconnaissance roles with a wide range of weapons, including nuclear. It will: (1) reach twice the speed of sound at altitude; (2) be capable of high subsonic speeds at ground level; and (3) have short take-off and landing capabilities from inferior surfaces.

The Minister of Defence said, when announcing the order: "It is believed that no other single aircraft in the world can match the performance of the TSR 2 in all three respects." The TSR 2 will be powered by the Bristol Siddeley Olympus turbojet.

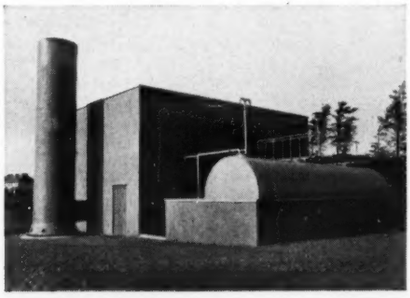
The Bristol Siddeley Olympus has proved itself in service to be one of the most successful turbojets ever built. Its truly astonishing built-in potential has been strikingly demonstrated by the threefold increase in power from the 11,000-lb thrust of the original production engine to the 33,000-lb thrust with reheat of the latest version. The Olympus, which has already helped the Avro Vulcan V-bomber to achieve its outstanding performance, embodies all the qualities essential for the efficient propulsion of a supersonic aircraft: high power at high altitude; remarkable handling characteristics; extremely low fuel consumption; great operational flexibility; a long overhaul life; and the highest power for its weight of any high-thrust turbojet.

The Olympus is eminently suitable for Britain's civil supersonic transport.



POWER FOR THIS

The Bristol Siddeley Olympus high-thrust turbojet powers the Avro Vulcan V-bomber.



... AND THIS

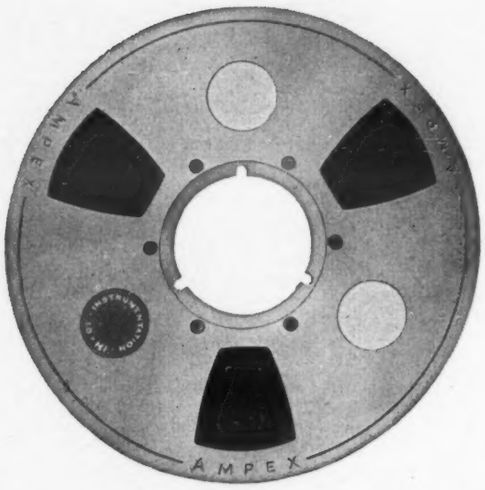
The Bristol Siddeley Industrial Proteus gas turbine engine powers a 3-mW turbo-generator.

... AND THIS

The Bristol Siddeley Marine Proteus powers the "Brave" class 96-ft Royal Navy patrol boats.

BRISTOL SIDDELEY ENGINES LIMITED

Central Office: Mercury House, 195 Knightsbridge, London SW7 · Aero-Engine Division: PO Box 3, Filton, Bristol, England · Power Division: PO Box 17, Coventry, England



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are premium quality magnetic tapes designed for analogue recording by any of the basic techniques. Magnetic properties include high sensitivity, and a wide dynamic range with a stable output throughout the life of the tapes. Exceptionally smooth, hard surfaces provide cleaner operation with less oxide shed, offering greater reliability and reduced maintenance. These tapes are available in configurations for a wide variety of applications. They are offered on acetate or Mylar* backing films, in thicknesses of 0.6, 1.0 and 1.5 mils, and in various widths and lengths. All are supplied on high-performance Ampex Precision Reels or on NAB-type reels. For application information write to Ampex Great Britain Limited, Arkwright Road, Reading, Berkshire, England. AMPEX

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INTERAVIA AIR LETTER reports...

(contd. from page 271)

Aircraft and Powerplants

Canadair Ltd., of Montreal, announces a number of performance improvements in the Canadair CL-44 four-engine transport aircraft. The range has been increased by 6 percent (280 nautical miles), while the cruising speed has been raised by 3.5 percent or 11 knots over the original performance guarantee. The take-off and landing runway lengths have been reduced by 11 to 12 percent. Take-off runway length with maximum take-off weight is now 6,800 ft; landing runway length with maximum landing weight is 5,980 ft. The swing-tail CL-44 began flight tests on November 16th, 1960, and official type certification tests are now at an advanced stage.

●

Two de Havilland Gyron Junior DGJ.10 turbojets with reheat powered a modified Gloster *Javelin* which made its first flight on January 31st. The main objective of the programme is to test the reheat *Gyron Juniors* before the first flight of the Bristol T.188 research aircraft for which they have been developed. The DGJ.10, which at sea level develops a basic dry thrust of 10,000 lb, will give a thrust with reheat of over 20,000 lb at 36,000 ft and at speeds in excess of Mach 2.5. The reheat system, which has also been designed by de Havilland, operates at the exceptionally high temperature of 2,000°K. An earlier version of the *Gyron Junior* (without reheat) is in production for the Blackburn *Buccaneer* low-level strike aircraft ordered in quantity for the Royal Navy.

●

Sud Aviation has equipped an *Alouette II* with a Turboméca *Astazou II* shaft turbine with a view to further development of the *Alouette* helicopter; tests began on January 31st. The *Astazou II*, which received official type certification only recently, is rated at 530 h.p. for take-off (554 e.h.p.). Maximum continuous rating 480 h.p. and cruise rating 420 h.p. Standard equipment for the *Alouette II* is an *Artouste II* with a take-off rating of 400 h.p.

●

The Canadair 540 is now equipped with a turbine-powered airborne auxiliary power unit (APU) to make the aircraft independent of ground support equipment. The APU gives engine starting, cabin air-conditioning and a d.c. power supply. The Canadair 540 is also offered with a new 60 seat cabin layout.

●

De Havilland intends to develop a new executive aircraft, designated DH.125, according to London aviation circles. This aircraft, of which two prototypes would be built, would be powered by two rear-mounted jet engines and could transport up to eight passengers. There is also talk of de Havilland's producing a military version. Mention has also been made of the DH.126, a stretched version of the DH.125.

The DH.123 project (two *Gnomes*), which was originally intended as a successor to the DC-3, has now been dropped.

●

Avia 14-Super is the designation of a 42 seat version of the twin-engine *Avia 14* airliner. The *Super* version has auxiliary wing-tip fuel tanks. Delivery of the *Avia 14-Super* to Rumania has been completed, and the series has been phased out of production.

Flight Testing and Type Certification

The U.S. Army has stepped up its testing programme for the Grumman AO-1 *Mohawk* observation aircraft. The Army Transportation Materiel Command will subject the aircraft to temperatures ranging from —55°C to +20°C in a climate laboratory at Eglin AFB, Florida. Two other AO-1s are undergoing logistic tests, including 1,000 hours of flight stress to a simulated several years of normal operation. Testing is expected to be completed this spring.

●

The Chance Vought F8U-2N Crusader has completed its carrier qualification tests, and the first deliveries have been made to a Marine Corps fighter squadron. A number of aircraft of this type have also gone to Navy training squadrons at Cecil Field, Florida, and Moffett Field, California. The F8U-2N is fitted with a Pratt & Whitney J57-P-20 engine of 18,000 lb thrust with afterburner. The armament consists of four *Sidewinder* air-to-air missiles; the aircraft also carries four 20 mm guns and can take unguided 2.75 inch rockets in a launcher in the fuselage.

The AMPEX CP-100 is a compact, extended-frequency instrumentation tape recorder/reproducer. Tape transport, motor drive amplifier, heads, power converter, controls and all-transistorized plug-in record/reproduce electronics are contained in a single 13¼" x 19" x 33¼" mobile case. The CP-100 operates on 28-volt DC, with 48 to 400 cycle converters available for other power sources. Data is recorded by direct or FM carrier techniques on up to 14 analogue tracks. The CP-100 offers frequency response to 200 Kc at 60 ips or expanded recording time of 24 minutes for 100 Kc data at 30 ips on a standard 10½" reel. Transport tape speeds – 1⅞, 3¾, 7½, 15, 30 and 60 ips – and plug in frequency determining units and equalizers associated with tape speeds, may be quickly changed. The versatile and mobile CP-100 performs reliably over a temperature range of from −50° F to +160° F, up to an altitude of 10,000 feet, in relative humidities to 95%... and is designed to withstand shocks and vibrations encountered in rugged mobile testing applications. This recorder may also be rack mounted if desired. For complete details write Redwood City Engineering Ltd., Arkwright Road, Reading, Berks., England. AMPEX

BEA VANGUARD

BUILT BY VICKERS POWERED BY ROLLS-ROYCE

Newest in air travel

March 1961 is an important month for people who fly. For that is when BEA introduces the brand-new Vanguard jet-prop airliner on their Paris service. Built by Vickers, the Vanguard has been specifically designed to meet the tremendous increase in European air travel. It is one of the largest airliners in the world, seating over 100 passengers in four spacious cabins. Four Rolls-Royce Tyne jet-prop engines power the Vanguard. Extra-large freight holds and quick turn-round facilities ensure that it pays its way, all the way. By introducing the Vanguard, BEA will be able to offer you more services with more seats available on them.

fly BEA

JET CLEARANCE WITH ONE RADAR

FROM TAKE OFF TO 150 MILES PLUS

WHATEVER THE TERRAIN–WHATEVER THE WEATHER

S. 264A THE MOST ADVANCED AIR TRAFFIC CONTROL RADAR IN THE WORLD

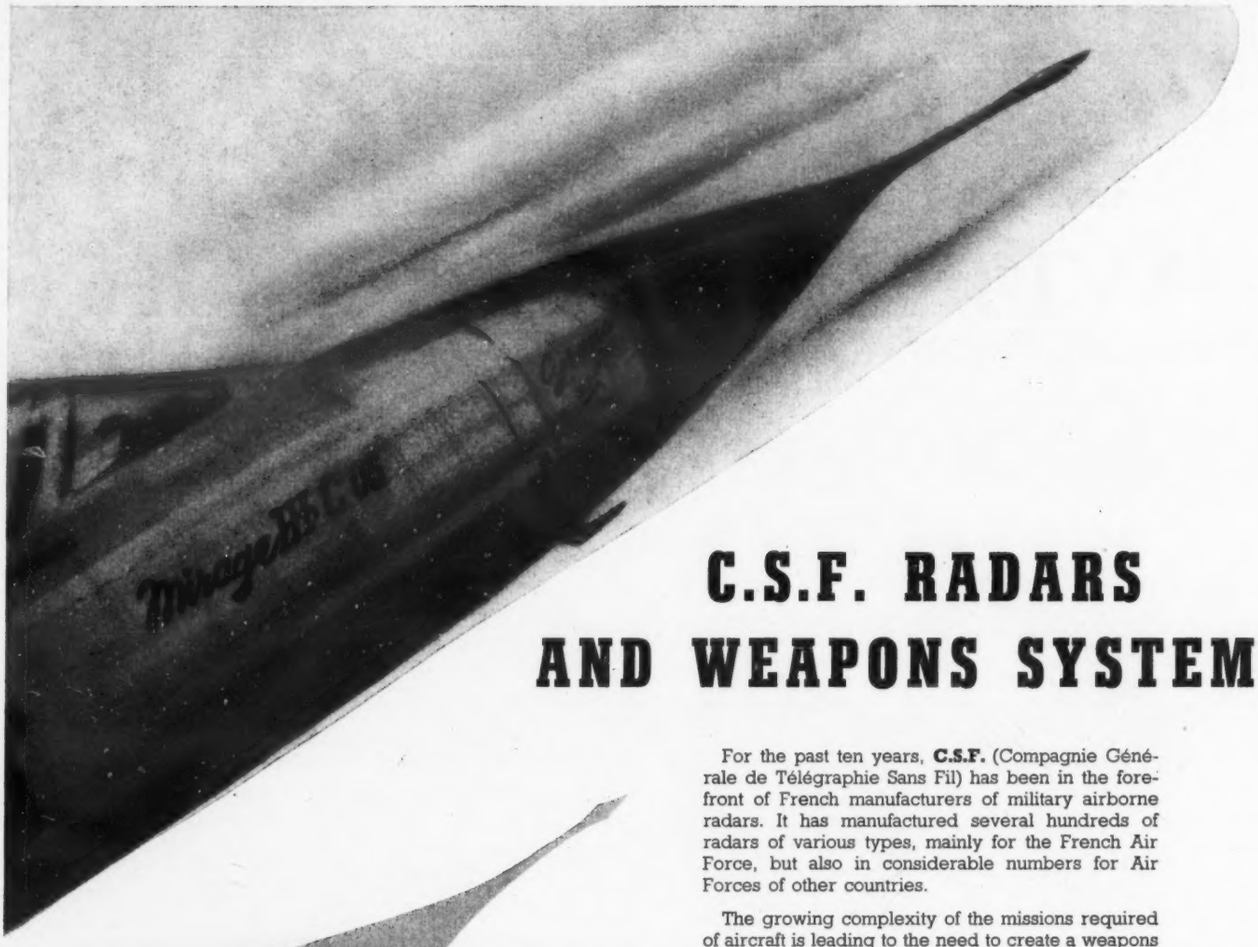
Marconi 50 cm. Radar is immune from weather effects without polarisers and has a fully coherent crystal controlled MTI system.

30 MARCONI *50* CM. RADARS HAVE BEEN ORDERED OR INSTALLED IN THE U.K., EUROPE, ASIA, AFRICA AND AUSTRALASIA.

MARCONI

COMPLETE CIVIL, MILITARY AND NAVAL RADAR INSTALLATIONS

MARCONI'S WIRELESS TELEGRAPH COMPANY LIMITED, CHELMSFORD, ESSEX, ENGLAND

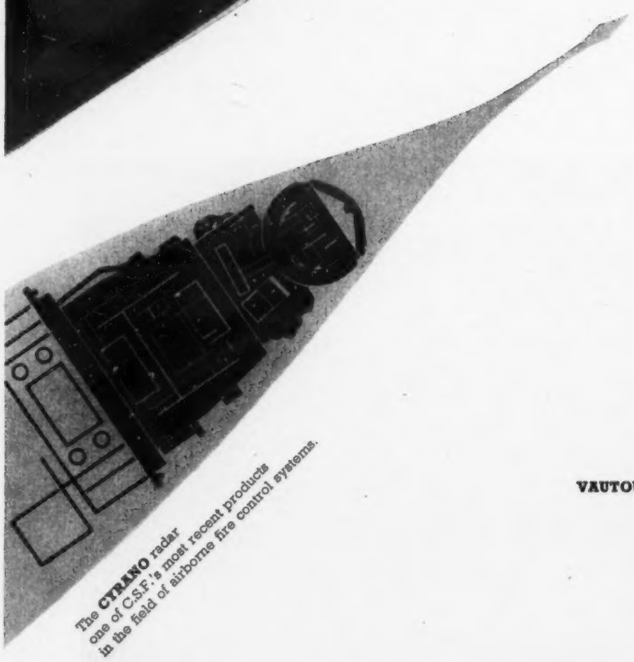


C.S.F. RADARS AND WEAPONS SYSTEMS

For the past ten years, **C.S.F.** (Compagnie Générale de Télégraphie Sans Fil) has been in the forefront of French manufacturers of military airborne radars. It has manufactured several hundreds of radars of various types, mainly for the French Air Force, but also in considerable numbers for Air Forces of other countries.

The growing complexity of the missions required of aircraft is leading to the need to create a weapons system of which radar is an integral part.

C.S.F.'s research and production departments, which have already developed such equipment, have acquired the experience necessary to solve all the problems posed by the design and manufacture of aircraft and missile radars and their integration into weapon systems.



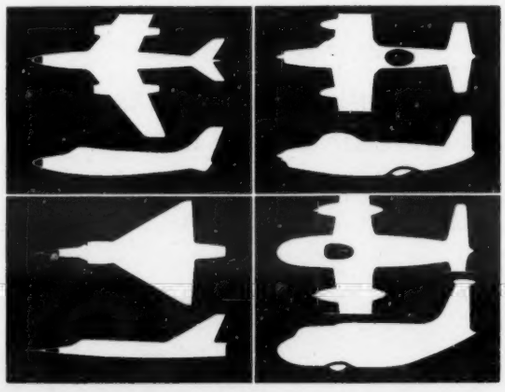
The **CYRANO** radar one of C.S.F.'s most recent products in the field of airborne fire control systems.

VAUTOUR

ALIZÉ

MIRAGE III

ATLANTIC



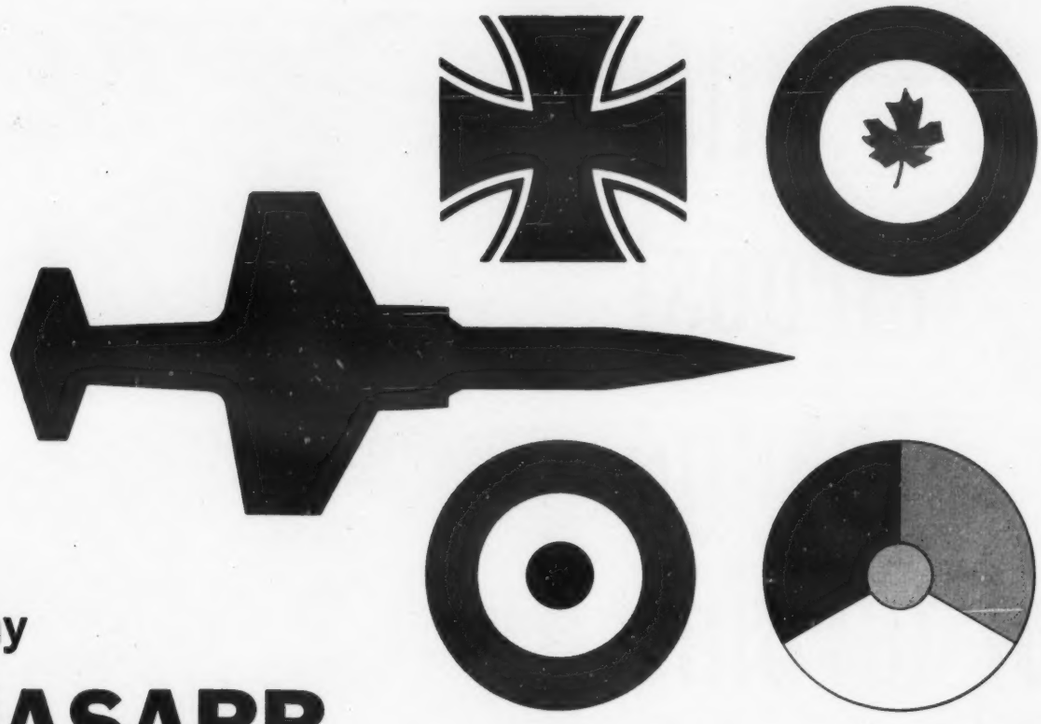
C.S.F

GROUPEMENT MILITAIRE

SERVICES COMMERCIAUX "FRANCE" : 66, AVENUE PIERRE BROSSOLETTE - MALAKOFF - ALE. 69-60

GILBERT BRIOT

SERVICES COMMERCIAUX "EXPORTATION" : C. S. F. DIVISION INTERNATIONALE - 79, BOULEVARD HAUSSMANN - PARIS 8e - ANJ. 84-60



Why

NASARR

is the chosen Radar System for NATO's F-104's

For maximum effectiveness in its Lockheed F-104's, NATO needed a versatile and reliable radar system of extremely advanced capabilities. NASARR meets this need. It is the *only* radar system in production for the Free World that can perform all these functions:

1] Air-to-air search 2] air-to-air blind acquisition and automatic tracking 3] air-to-air visual acquisition and automatic tracking 4] ground mapping 5] contour mapping 6] terrain avoidance 7] air-to-ground slant ranging.

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The NASARR monopulse radar systems are small in size, extremely light in weight and highly reliable. These systems are in quantity production... are already in service... and are available for delivery.

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Strasbourg Proposals for European Space Research

At the end of January a sixteen-State conference [1]), held in Strasbourg under the auspices of the Council of Europe, deliberated on the feasibility of a European space research programme.

The plan set forth in the conference's final report is a modest one: the launching of three satellites—a pitch-stabilized satellite weighing 1,000 to 2,000 lb, to be put into a low orbit and to serve mainly for astronomical observations; a smaller satellite, weighing roughly 250 lb, to be placed in an eccentric orbit for investigation of the earth's gravitational and magnetic fields, cosmic radiation and the exosphere at distances of up to three times the earth's radius; a 100 lb satellite which, orbiting on a highly eccentric trajectory distances of up to 25 times the radius of the earth), will be used to investigate the solar atmosphere and possibly as a telecommunications relay station.

As these research goals are not entirely new, one is inclined to wonder whether the Europeans are not a little late for the party with their space programme. As early as 1958, when the Space Research Committee of the American House of Representatives recommended the creation of an international space research organization, it expressed doubts as to whether Western Europe could put a space vehicle onto its trajectory without American aid. In other quarters, too, it was felt that the development of European boosters for space probes would mean merely a costly duplication of preliminary work already done by the USA and the Soviet Union.

If, however, we look into the matter more closely, such doubts as to the feasibility of a European programme are dispelled. The first objection—that the Western European nations are incapable of building their own boosters—is rendered invalid by British and French developments of recent years, in the shape of *Black Knight, Blue Streak* and *Véronique*. As for the second objection, neither the Americans nor the Russians have shown themselves particularly communicative as regards their "preliminary work" in the field of boosters—an attitude which is understandable in view of their military secrecy requirements but which does not alter the fact that Western Europe can expect little in the way of assistance from the USA. And as for the Soviet Union...

It is therefore hardly surprising that ten West European States set up the Groupe d'Etudes Européen pour les Recherches Spatiales (GEERS) in Paris in June last year, that they met in CERN in Geneva for the first time in November and that now, at Strasbourg, they have sought to lay the foundations for a common research and development programme on a wider basis.

The Strasbourg conference was based on a detailed 113 page committee report, expressed in terms which leave no doubt that Western Europe will by no means be content with three research satellites, but even today has more ambitious long-term aims. The fact that the report devotes much space to future possibilities for rocket propulsion—nuclear fission, nuclear fusion, ion-beam propulsion, solar energy, plasma and photon rockets—is highly significant. Admittedly, these hints of things to come are all compressed into the introductory, purely theoretical chapter of the report and are not mentioned in the final proposals; nevertheless, they figure in the practical survey of the technical, scientific and economic benefits which Europe is likely to derive from space research.

On the technical side, the report mentions rocket propulsion, and has the following remarks to make regarding telecommunications: "To send messages over the great distance of space we need to be able to detect weak signals in a background of noise. It is possible to develop transmitters and receivers of much greater precision than hitherto, particularly with respect to frequency control... The engineers who have learned how to do it will be able to design instruments and equipment for radio and for measurement which industry will find invaluable in the next decade."

The report lays particular stress on the economic aspects: "The commercial justification for space research arises from the fact that it involves the development of new technologies which will become the industrial techniques of the future. If member countries do not develop these, they will become scientifically and technologically under-developed countries, unable to maintain themselves in the forefront of industrial development."

The final chapters of the report investigate ways and means by which the nations of Europe can succeed in their endeavours to promote space research. Here the policy of "going it alone" is rejected, not only for States with less well-developed technologies, but also for Powers such as France and Britain, who have already developed rockets of their own. For it is estimated that future research tasks would far exceed their financial resources. The only course open to Western European nations, says the report, is cooperation. It stresses, however, that Britain has already done valuable preliminary work on her own, having spent £65 million on the *Blue Streak* rocket to date. What is more, it adds, the advantages of multi-national operation of the Woomera range and the British observation stations should not be underestimated.

The Strasbourg proposals more or less follow the line taken by the report. It is recommended that a three-stage booster be built, with *Blue Streak* as first stage, a developed *Véronique* as second stage and a third stage built by a number of firms, probably in continental Europe. Although test firings of the separate stages could begin in about two years' time, the first fully tested booster would not be able to place a satellite in orbit until about 1965.

About £70 million will be needed for the construction of the rocket and other initial expenses (British first stage 55%, French second stage 18%, third stage 9%, experimental rockets 10%, sundry expenses 8%). The contributions of individual States will be as follows (thousands of pounds): Great Britain £23,333; France £14,399; German Federal Republic £13,244; Italy £6,846; Spain £2,063; Sweden £2,033; Belgium £1,993; Netherlands £1,850; Switzerland £1,582; Denmark £957; Austria £927; Norway £773.

Although no attempt is made to assess the benefits which this plan will bring to the industries of individual States (including the equipment industry), there can be no doubt that the European space research programme will be by no means an unsound investment for certain nations. But for the moment this is not the main point at issue. What really counts, according to the Council of Europe report, is whether Western Europe is prepared to let herself be overshadowed by the two great rocket powers in West and East, or whether she is willing to strike out on her own and learn the new techniques. Although the rapporteur gives repeated assurances that nothing is farther from his mind than military considerations, this does not alter the fact that they are implicit in certain parts of the report. On page 30, for instance: "The military use of satellites is ignored in this Report, being outside my terms of reference; but in terms of power politics they cannot be ignored." Finally, there is no overlooking the fact that the Strasbourg conference proposes a set of stern, almost military-sounding statutes for the European space research orgization in general and for the organisms responsible for satellite launching in particular, causing one delegate to remark on the undeniable affinity between the planned institution and the NATO system.

[1] In addition to the 15 members of the Council of Europe — Austria, Belgium, Denmark, France, German Federal Republic, Great Britain, Greece, Iceland, Ireland, Italy, Luxemburg, the Netherlands, Norway, Sweden, Turkey — Spain was represented, and the Commonwealth States sent observers.

INTERNATIONAL MEETINGS AND CONFERENCES

Mar. 13th-22nd: International Technical Fair. Utrecht.

Mar. 14th: ICAO, Subcommittee of the Legal Committee on Aerial Collisions. Paris.

Mar. 14th-16th: National Rocket Club and Missile/Space Industry, Fourth Annual National Missile/Space Conference and Dr. Robert H. Goddard Memorial Dinner. Washington, D.C.

Mar. 14th-17th: Electronic Industries Association, Seminar on "Planning for Limited War Requirements" and EIA Spring Conference. Washington, D.C.

Mar. 16th-18th: Fifth National Conference on Aviation Education. Washington, D.C.

Mar. 20th: IATA Traffic Handling & Accountancy Working Group. New York.

Mar. 20th-23rd: Institute of Radio Engineers, International Convention. New York.

Mar. 20th-24th: American Society for Metals, Western Metal Exposition. Los Angeles, Calif.

Mar. 20th-25th: Radio and Electronic Engineering Exhibition and Convention. Sydney, Australia.

Mar. 21st-23rd: American Power Conference. Chicago, Ill.

Mar. 27th-31st: New York University International Seminar on the Economics of Air Transportation. New York.

Mar. 27th-31st: National Symposium on "Temperature—Its Measurement and Control in Science and Industry." Columbus, Ohio.

Mar. 28th-29th: American Nuclear Society, Nucleonics in Flight Symposium. Dallas, Tex.

Apr. 4th-5th: Aviation Technician School Administrators Conference. Lafayette, Ind.

Apr. 4th-6th: American Rocket Society, Lifting Re-entry Vehicles: Structures, Materials and Design. Palm Springs, Calif.

Apr. 4th-6th: International Symposium on Electromagnetics and Fluid Dynamics of Gaseous Plasma, sponsored by IRE, IAS and U.S. Defense Research Agencies. New York.

Apr. 4th-7th: SAE National Aeronautical Meeting. New York.

Apr. 7th-8th: COSPAR International Space Research Meeting. Florence.

Apr. 8th-16th: Singapore Government, International Air Show. Singapore.

Apr. 10th: IATA TC2 Agency Committee. Paris.

Apr. 10th-11th: Air Industries and Transport Association Semi-Annual Meeting. Victoria, B.C.

Apr. 10th-11th: Western States Section of the Combustion Institute, Aeronutronics Division of Ford Motor Co., Spring Meeting. Newport Beach, Calif.

Apr. 10th-14th: FAA Meeting. Atlantic City, N.J.

Apr. 13th: IATA Taxation Subcommittee. Paris.

Apr. 13th-14th : Institute of the Aerospace Sciences/Army Aviation Meeting (classified). Washington, D.C.

Apr. 17th-18th: IATA, 14th Technical Conference. Montreal.

Apr. 17th-28th : International Airport Association, 14th Technical Conference. Montreal.

Apr. 18th : IATA Legal Committee. Paris.

Apr. 18th-20th: Airlines Electronic Engineering Committee, Maintenance Meeting. Atlanta, Ga.

U.S. Bankers Speak of an Air Transport Crisis

BY SCOTT HERSHEY, NEW YORK

Although the following report on the warning given by the Investment Bankers Association contains no sensational novelties, the editors feel that it will be of interest to readers, as the Association's recommendations appear to herald a new wave of protectionism in the American air transport industry, similar to those which have repeatedly hampered the operations of European carriers in the U.S. in recent years. Significantly, the Civil Aeronautics Board announced at the beginning of February, 1961 that in future foreign carriers would not be authorized to operate to points in the USA unless they produced freight and passenger statistics and flight plans. Pan American World Airways went a step further and demanded that CAB require foreign companies to submit details of pool agreements which they have concluded.

In justification of these measures, which have apparently not been discussed with the Department of State, CAB claims that similar steps have been taken by a number of foreign authorities against American operators, thereby placing undue restrictions on the seating capacity which they can offer. CAB's action has led to protests from a number of European airlines and, what is more, from American carriers. Whether the New World and the Old are preparing for a further outbreak of the "cold war" will become clear in the coming months.

Editors.

In a recently published bulletin, the Aviation Securities Committee of the Investment Bankers Association of America has warned that the "aviation industry of the United States is within a period of crisis."

"At the moment the industry is doing its job with customary diligence, but its financial vigor has been seriously impaired and problems which confront it, if not solved soon, may cause the entire aviation complex of the nation to falter," the Committee said. "In a world where only the strong may feel secure, that would be a catastrophe."

Chairman of the Committee Herman H. Kahn, a partner in the highly respected Wall Street firm of Lehman Brothers, noted that most members of the Investment Bankers Association underwrite aviation securities or have clients who own them, and thus are qualified to speak from professional experience.

The Committee pointed out that the aviation industry is at once the most important industrial factor in the nation's military organization and the most dynamic element in its domestic and international transport system. It directly employs more than one million people, and in 1960 its gross sales and revenues exceeded $13 billion.

While the Committee gave considerable attention to the situation among the U.S. domestic trunklines and to the aerospace industry, we should like to discuss its remarks on the international carriers and their problems from the financial point of view.

The Committee noted that while all over the world international air travel is expanding dramatically, so is the competition for the business. For example, sixteen airlines, only two of which are U.S. carriers, now run scheduled flights over the North Atlantic route. Soon, another airline, Russia's Aeroflot, will further intensify the competition, as will also the scores of additional jet aircraft which are coming into international service.

Thus the root of the earning power problem which plagues our international airlines lies in the dismaying number of competitors. But numbers are not, in themselves, the actual core of the problem, for the potential traffic volume is large. For example, even though the U.S. share of the North Atlantic passenger traffic has sagged from 61% in 1950 to about 30%, revenues have roughly doubled and passenger miles flown have risen more than twofold.

Airlines that are run efficiently and imaginatively should, all things relatively equal, experience no more than normal competitive rigors in getting and keeping a satisfactory share of the market. But, says the Committee, "the real heart of the problem is that from the standpoint of our (U.S.) international carriers the competition starts on an unequal basis, and the imbalance is growing."

In domestic competition, the primary considerations are economic, and the battleground lies wholly within the homogeneous commercial system of the nation. Rules fair to all can be collectively shaped and enforced, and from time to time alterations can be made which will, in theory, keep the industry strong.

"No such theoretical paradise exists in international commerce," the Committee reported. "Central authority is absent. Moreover, to foreign carriers owned or controlled by their governments, and in this category are most foreign airlines, economic considerations relative to the airline as a separate financial enterprise are of little importance.

"Instead, the motivating factors are diplomatic prestige, national pride and strategic position. In sum, most foreign airlines need not concern themselves with earning a profit."

In the interests of preserving the high quality of service and the free enterprise status of the nation's international air transportation system, the Committee suggested :

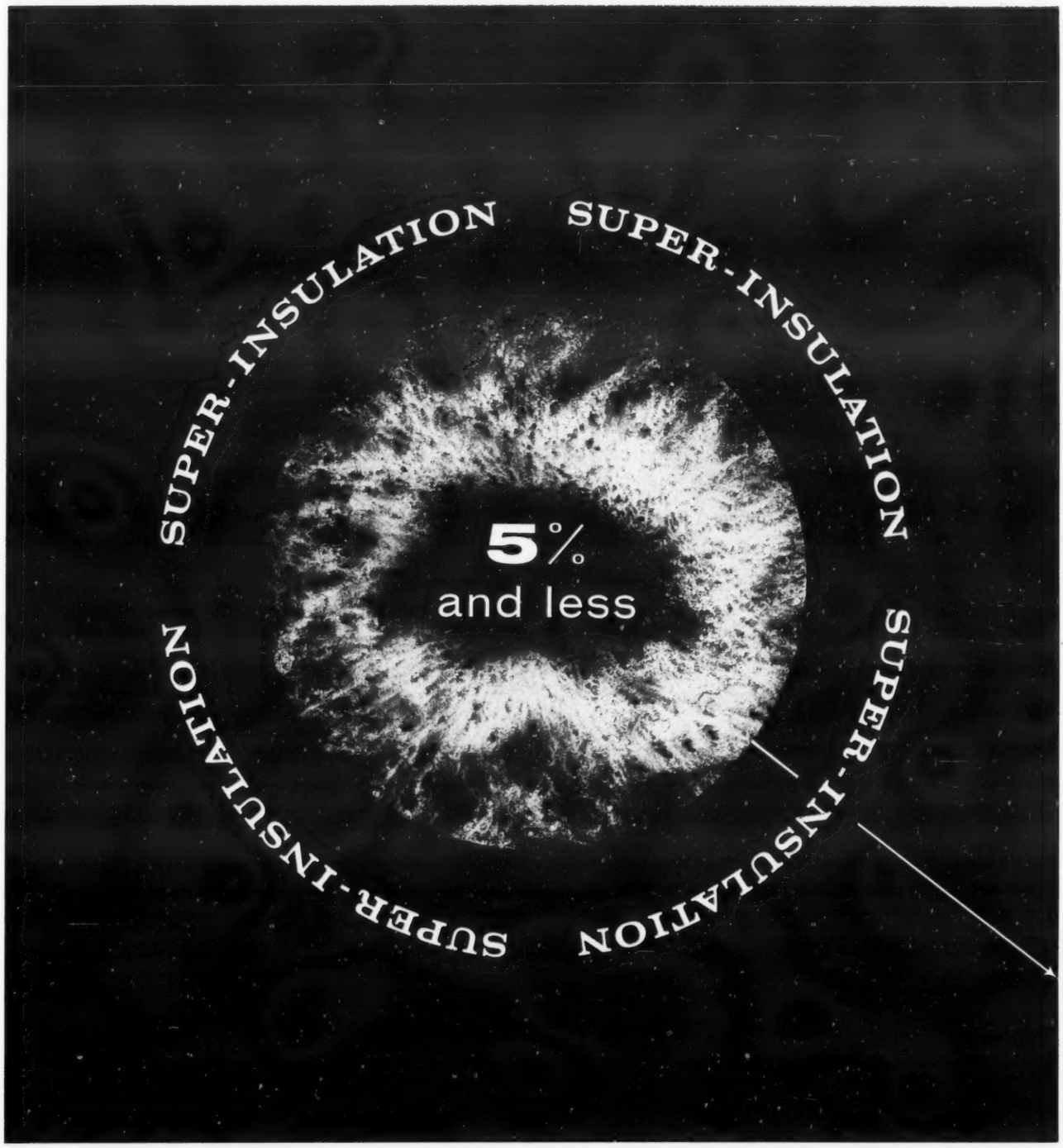
1 — That the Administration grant route awards to foreign carriers to serve the United States only after searching analysis of all the factors involved has shown how commensurate awards can be made to U.S. international airlines;

2 — That the Government and the airlines, international and domestic, further explore the possibilities of diverting traffic from MATS (Military Air Transport Service) to commercial carriers;

3 — That the orderly development of the air cargo industry be promoted by adjusting the present rate structure to encourage carriers to invest in new and improved equipment;

4 — That the Government and the agencies concerned intensify their studies of the matter of the supersonic transport aircraft;

5 — That attention be given to the advantages and disadvantages of a return to a policy favoring healthy competition.



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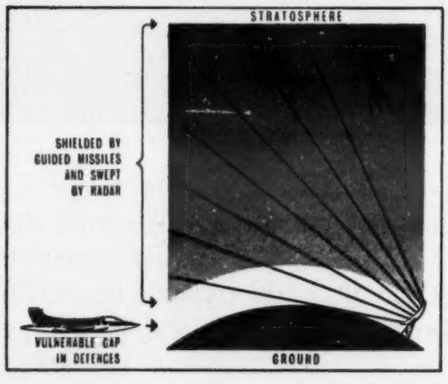

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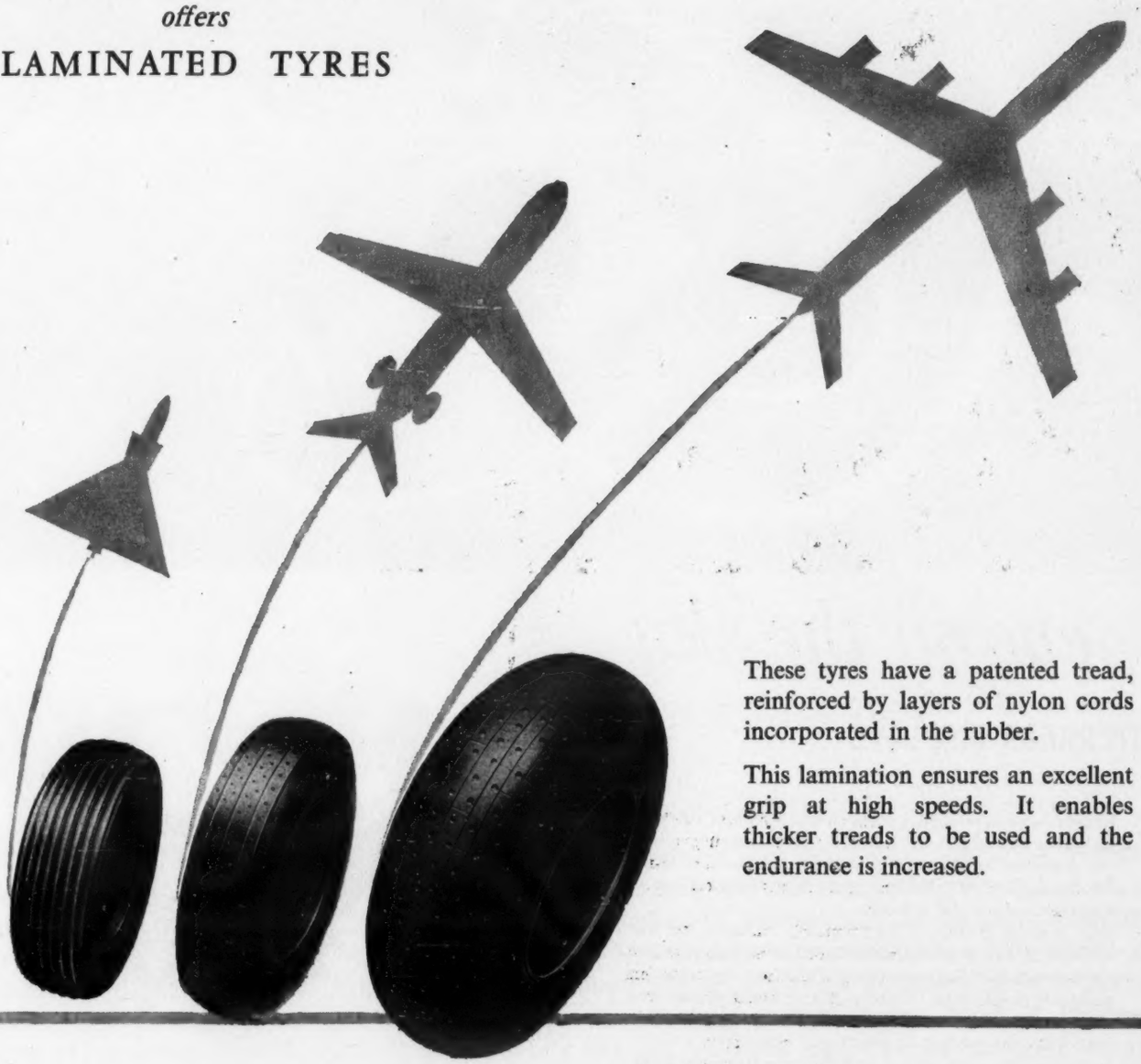

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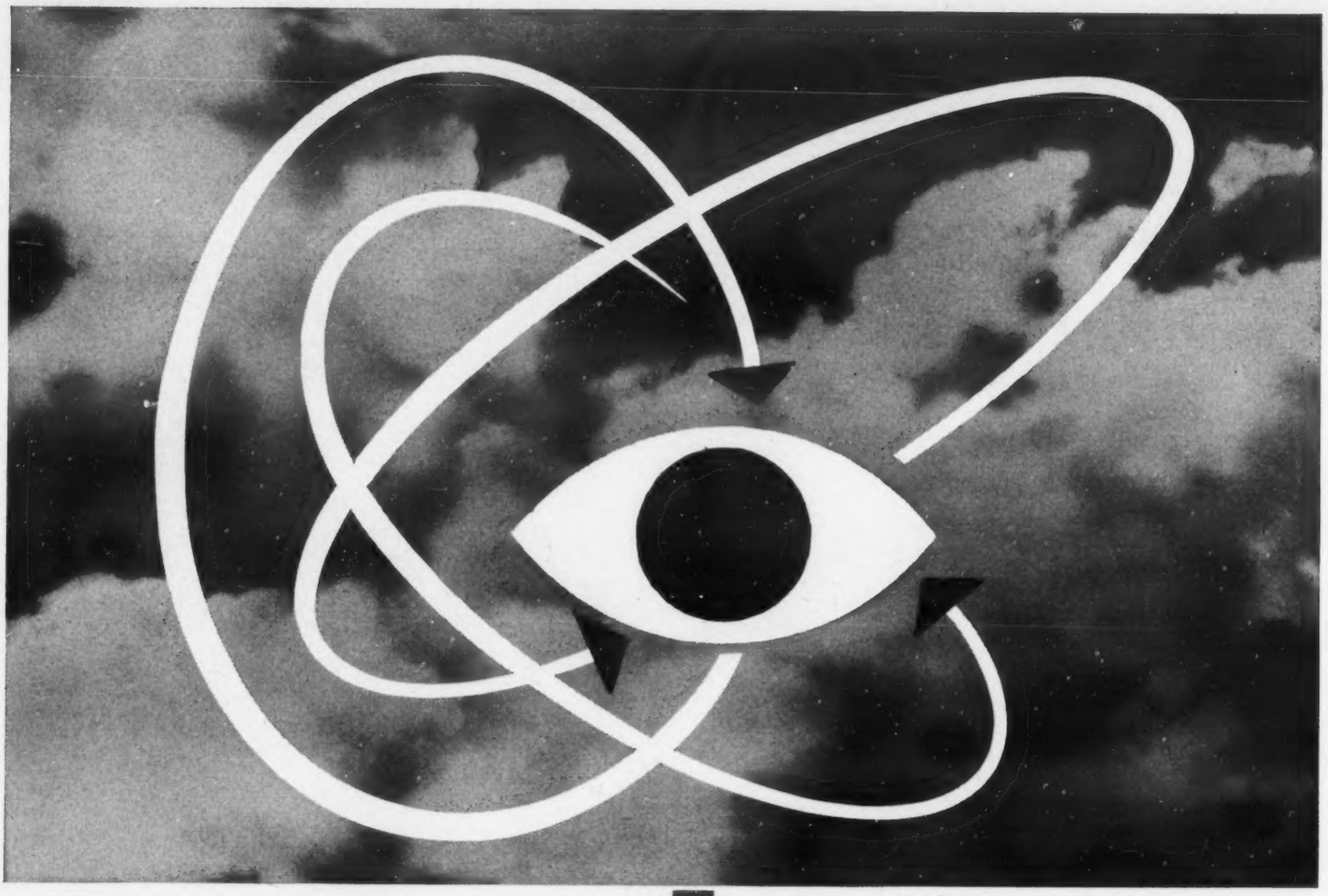

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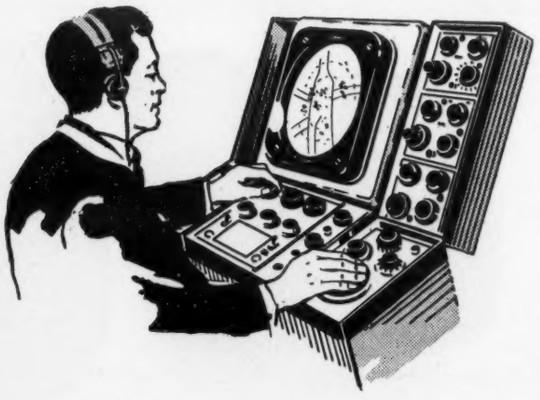

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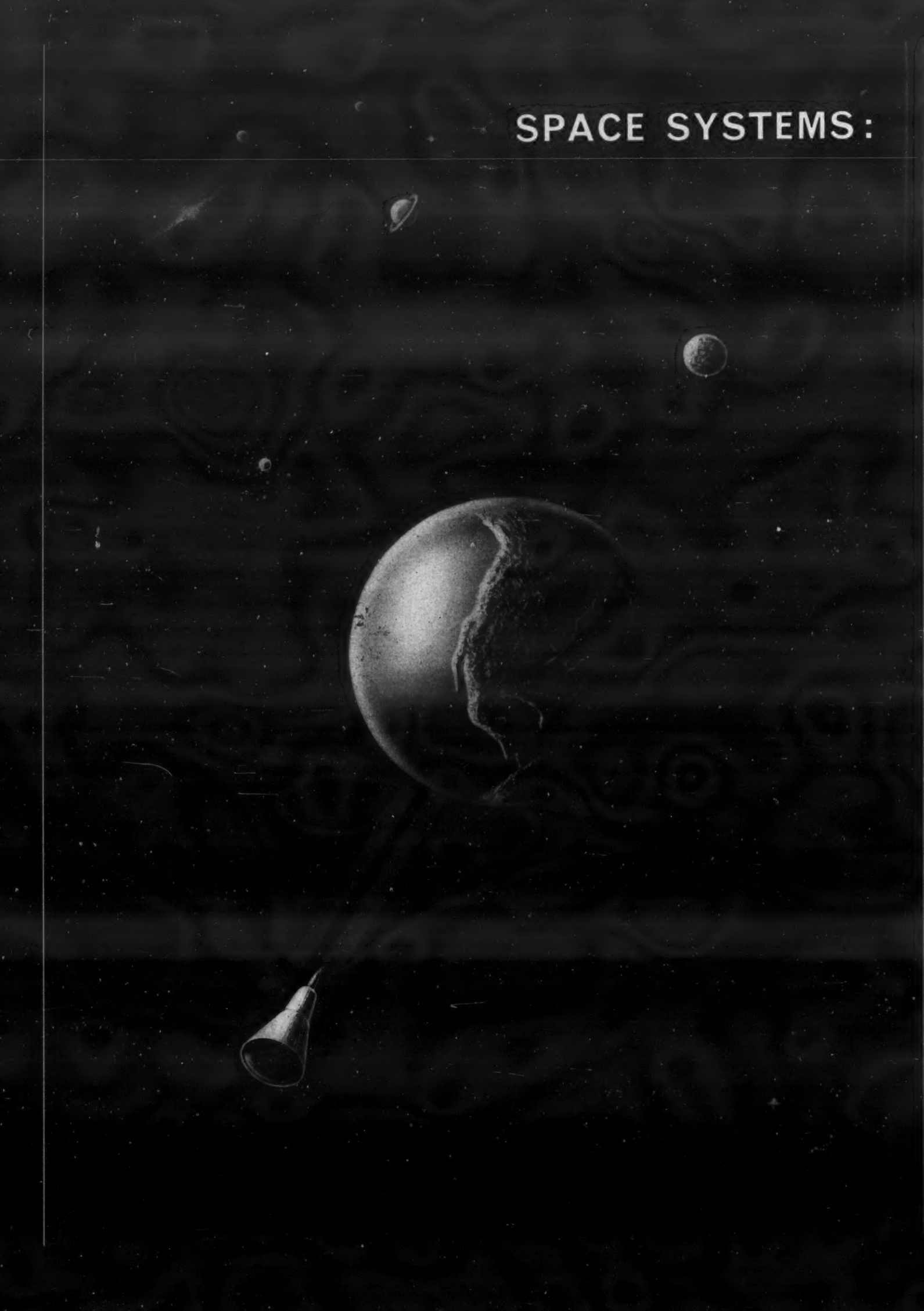

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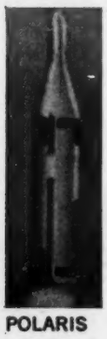

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POLARIS	NAVY AIRBORNE BOMB-NAV	POLARIS	B-58
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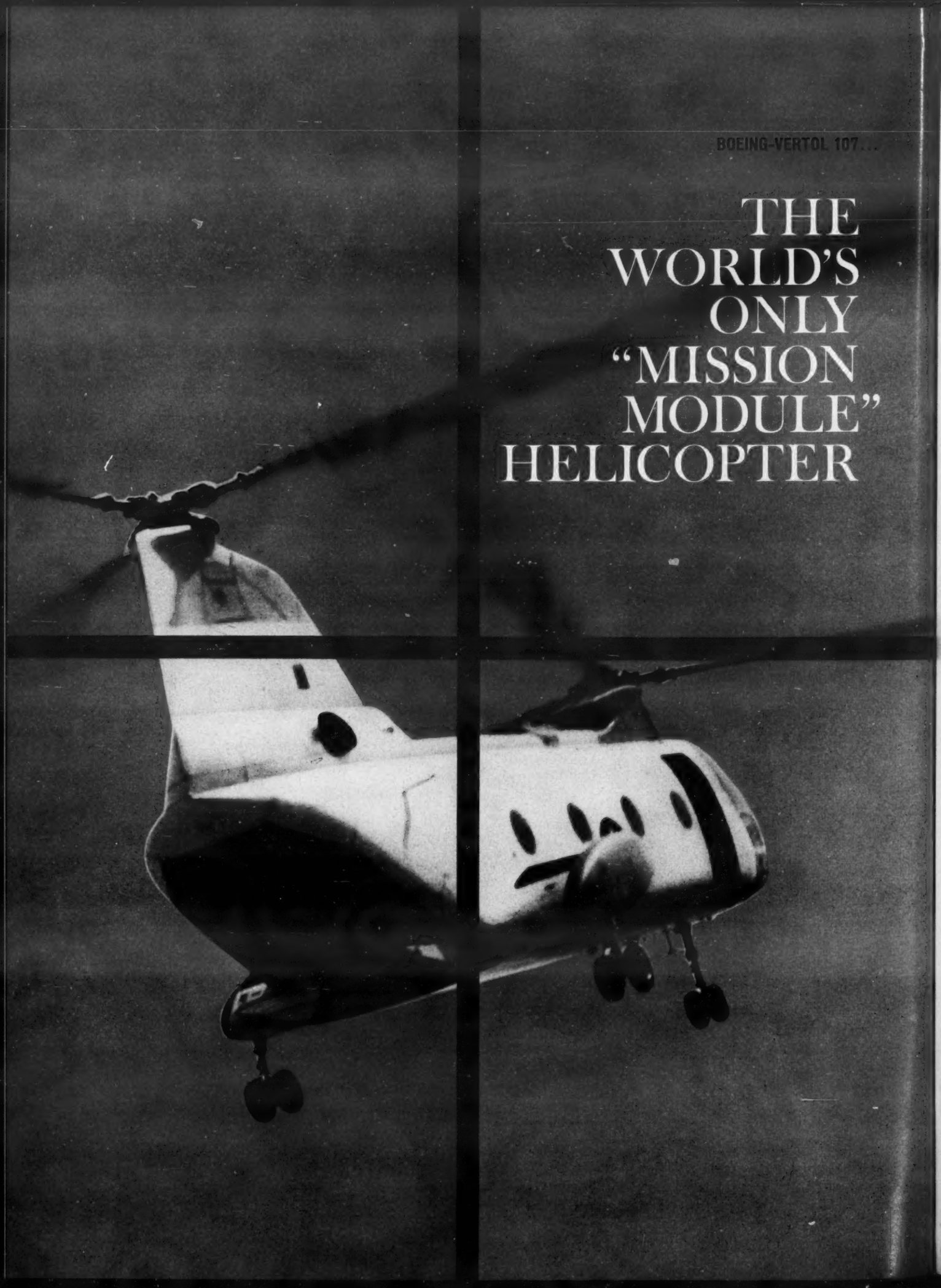
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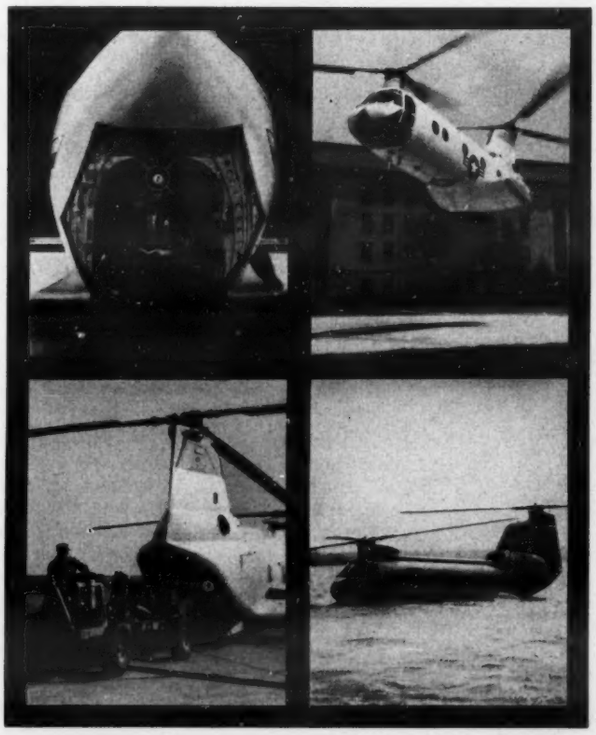

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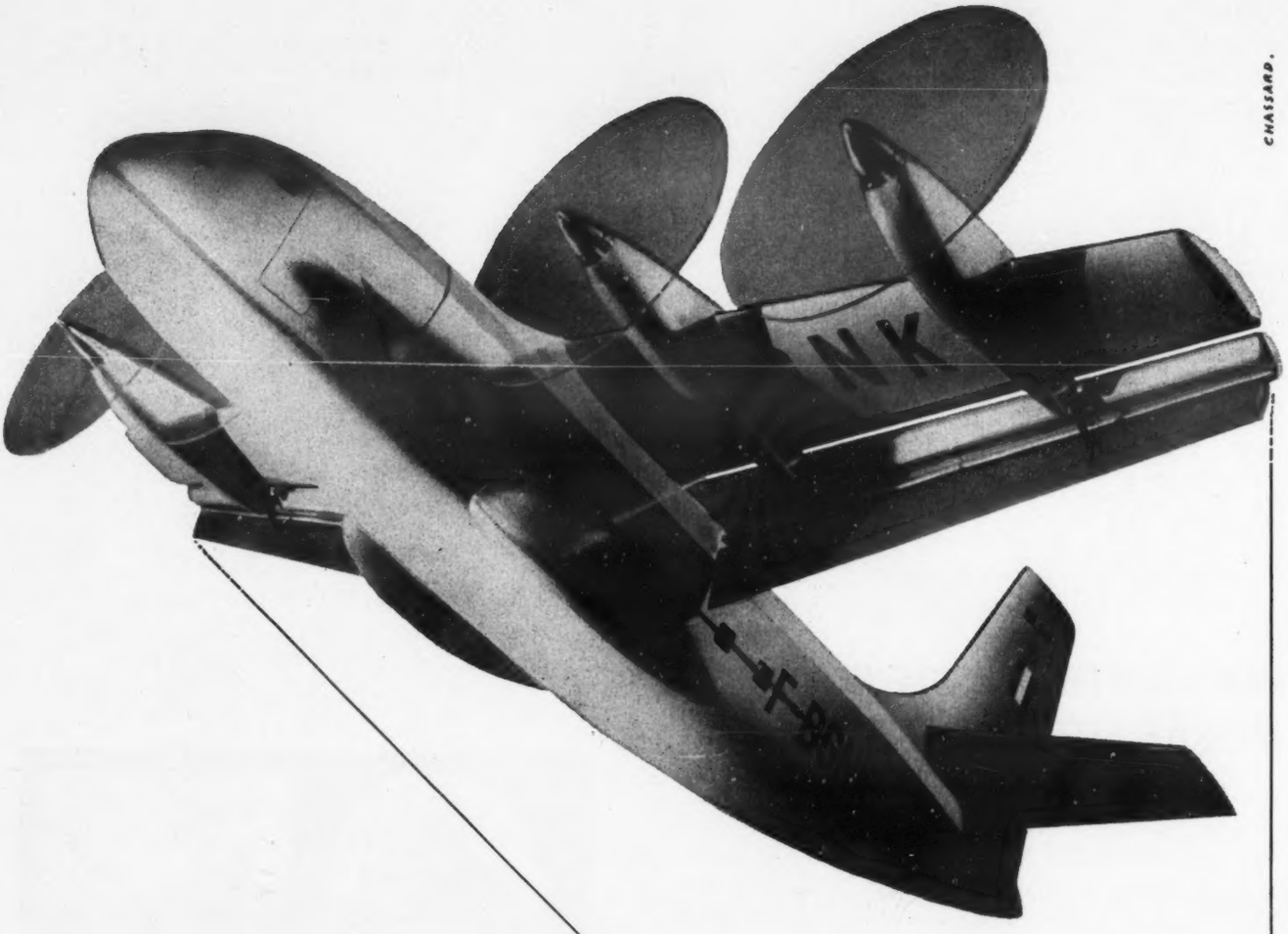

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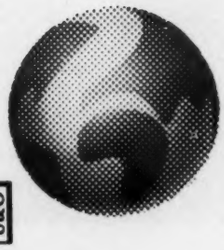

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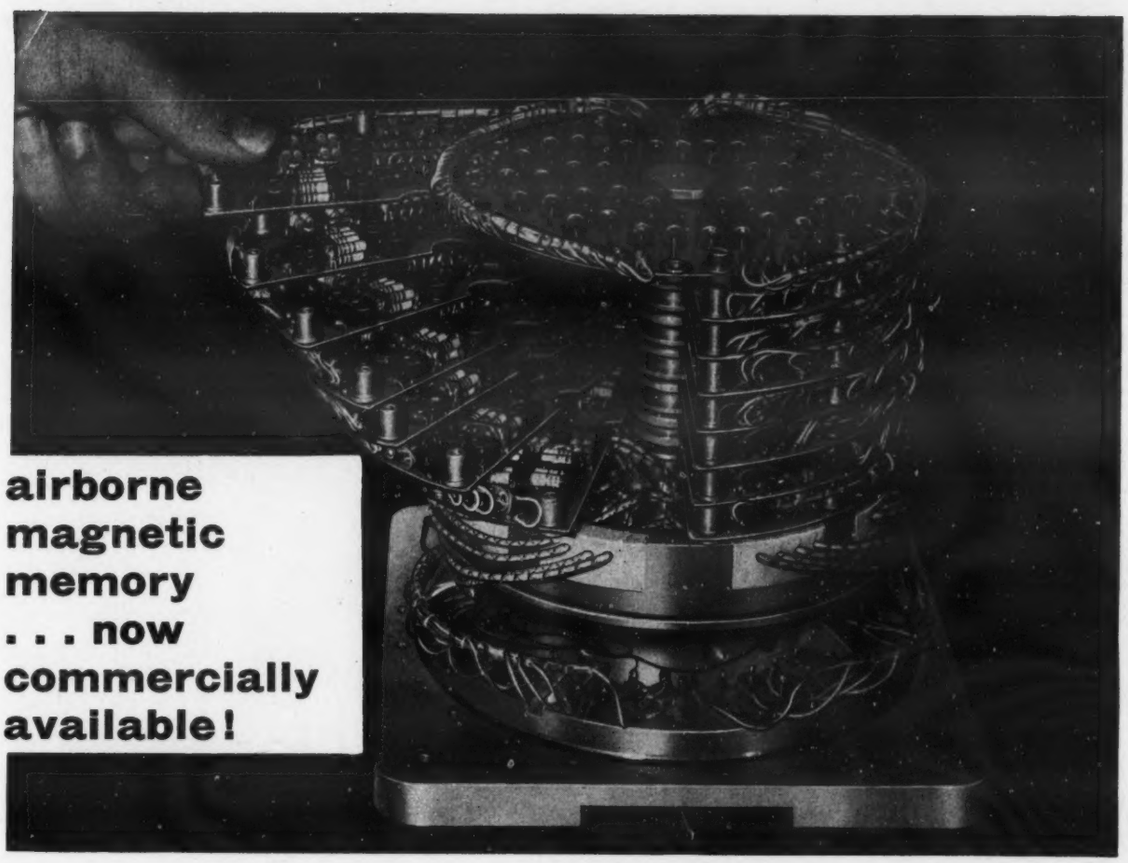

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Power Requirements — Watts (approx.)	
Motor Drive (115v, 400 cps, 3 phase)	12
Electronics (+5, −5, +10, +15v D.C.)	3 non-recording
Environmental	
Temperature-operating	0° to 85°C
non operating	−60° to 125°C
Shock	30g pulse
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Guided Weapons: Policy-Makers for Peace

For some time now the first *Atlas* missiles of 564 Missile Squadron, USAF, have been operational at Warren Air Force Base, near Cheyenne, Wyoming, thus bringing to a successful conclusion the first stage of the ten-year old American strategic plan for deterring aggressive powers by means of ICBMs with nuclear warheads. Although it will take the United States at least three years to achieve an adequate number of long-range rockets, the way in which the Soviet rocket threat against the West can be averted seems clearly indicated.

All the same, the constant advances in technology do not allow the strategists to sit back, for no relaxation can be allowed in the tremendous effort needed in order to keep the deterrent effective. From this effort more and more retaliation weapons are being born and the first generation *Atlas* and *Titan* missiles have already been followed by a second, typified by the three-stage solid-propellant *Minuteman*. To the nine *Atlas* bases, comprising 9–12 launching ramps each, were added nine *Titan* bases with up to 18 missiles apiece, and finally about 450 *Minuteman* launching silos are to be set up on three bases in the USA, each base comprising 3 squadrons of about 50 projectiles.

Meanwhile the first *Polaris* submarines have joined the American fleet. Although in its A-1 version the *Polaris* rocket has a range of only some 1,200 nautical miles, it can still, owing to the unlimited operational range of the carrier submarines, serve the ends of global deterrent strategy.

Special articles in this number deal with the tremendous progress embodied in the younger missile generation, and it is beyond doubt that the availability of these weapons provides the Americans with a powerful argument in negotiation.

The weapons appear well suited for the task of deterring the presumptive enemy from a rocket attack on the Western world for years to come, but in any case a substantial gain of time is assured.

There is also the question as to whether, particularly during the next three years which will see the completion of the missile bases already mentioned, the USA will also be able and willing to use her entire rocket forces in reply to an attack on one of her European partners in NATO. Following the avowal of the freedom of all nations made by President Kennedy on taking office, there can be no doubt that the U.S.A will never completely withdraw from Europe and isolate herself in her own continent. On the other hand it must not be overlooked that, now that the ICBM programme is underway within the framework of their deterrent policy, the Americans have become more independent of the European and Asian continents. In the event of an attack on an ally, they might well think twice about throwing the whole weight of their megaton warheads into the scales.

Another consideration is that, on the basis of retaliation forces at present planned, the USA would never be in a position to destroy all Soviet rocket and bomber bases at one blow.

For these and other reasons, both responsible planners inside NATO and American military thinking seem to be in favour of European deterrent forces, which would dispel the Russian appetite for confronting the USA with the delicate choice between waiting and launching a total nuclear war. A European retaliation force of this kind, to be likewise based on long-range rockets, would serve to remove any doubts on the part of the aggressor about an immediate European counter-blow and give greater weight to NATO policy as a whole.

Finally, the European members of NATO could in this way make a valuable contribution towards the cost of the strategy which has so far prevented the outbreak of a world conflict.

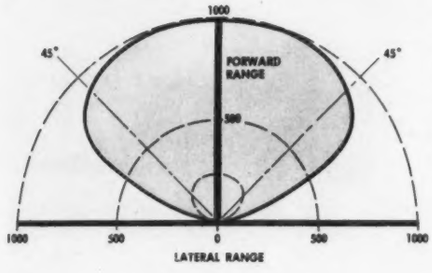
The arguments for and against deterrent forces of this type were thoroughly gone over at the last NATO Council meeting. Although no binding decision was reached on that occasion, a solution of one kind or another should be found to the controversial question of control of the atomic warheads.

The question which interests us here is what the shape of a long distance rocket intended for NATO should be, and who should build it. Large industrial concerns in France and Britain are indeed already working on the development of medium-range rockets; in France SEREB is interested in a solid-propellant rocket in the 2,000 mile class, and in Britain the Hawker Siddeley Group is prepared to undertake further development of *Blue Streak* (based on the work already done by de Havilland and Rolls-Royce in creating it), provided modest credits are forthcoming. However, for really useful work to be done, considerable sums would have to be made available. In the United States, programmes of this type have involved hundreds of millions of dollars, and Europe cannot expect to get results more cheaply. In any case, it would take years to create a European weapons system, whereas the *Polaris*, already operational in the USA, and the advanced version of the *Pershing*, which will shortly be available, could fill the gap. Both these weapon systems are relatively cheap, simple to maintain and extremely mobile.

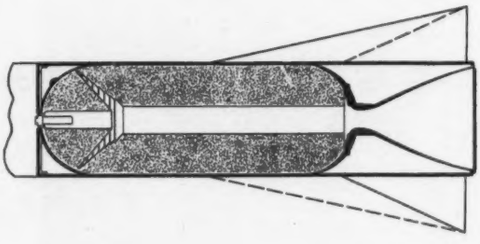
Shopping Spree. "That's settled then, we'll have four hundred of the solid fuel failure type, and six hundred second stage ignition trouble ones."
By permission of the "Evening Standard," London

Mobility is indeed of paramount importance, for Prime Minister Khrushchev's frequent threat that the whole of Europe lies within the effective range of thousands of Soviet rockets is to be understood in the sense that the Russians would employ their medium and short-range weapons against European NATO countries and therefore hit their targets with relatively high accuracy, whilst in order to reach European and Asiatic Russia, American long-range rockets would have to cover distances of 5,000—7,500 miles. The greater probability of the Russian missiles hitting their targets would therefore make it imperative for West European retaliation weapons to be extremely firmly entrenched in deep and hardened sites, as was originally intended for the British *Blue Streak* and also at first for the French medium-range rocket—unless mobile launching ramps, viz., special vehicles, railway wagons, surface craft or submarines are used.

Trial models of the *Skybolt* GAM-87 A air-to-ground missile on a carrier built by Douglas, under the wing of a Boeing B-52H.



The area shaded grey in the diagram shows the effective range of the *Skybolt* on both sides of the course steered by the carrier aircraft, indicated by the thick vertical centre line. After launching, the missile can be deflected sideways up to nearly 60 degrees, in which case the maximum range is, however, reduced from 1,150 miles to about 850 miles. This flexibility complicates the task of anti-missile defence for the enemy as well as permitting the carrier aircraft to alter course in the launch phase.



Diagrammatic cross-section of Aerojet-General's first stage rocket engine for the *Skybolt*. The engine and jet nozzle form a rigid unit and there is no jet deflector at all, the steering of the missile during the first stage combustion period being accomplished purely by the aerodynamic fins on the rear of the body.

This type of mobility in the European retaliation forces would spell uncertainty for the enemy, who would be kept constantly in the dark as to the exact position of the individual mobile rocket launching sites and would accordingly be obliged to apply a considerable preponderance of force in order to put them completely out of action.

The political implications of NATO retaliation forces of this kind have been exhaustively discussed and need not detain us here. This number of *Interavia* reviews the technical and military aspects of these weapons as well as of the tactical missiles required in Europe.

*

Meanwhile missile development in the USA is continuing at high pressure. The *Minuteman* is to be followed by a further generation of still lighter long-range rockets, for which draft project studies are at present in progress under the designation *Midgetman*. A launch weight of 12–15 tons has been mentioned, compared with the *Minuteman's* weight of about 30 tons. A clear picture of the progress achieved during the last few years in the development of rockets emerges from comparison of the launch weights with that of the *Atlas E*, which weighs at least 117 tons, requires much preparation and more complex ground installations, and cannot be made ready to launch in under 15 minutes. Moreover the *Midgetman* project is quite distinct from the recently announced *Muroc*, at present described by the USAF as the last word in missile technology. The structure of the solid propellant for this three-stage rocket is said to be such that the propellant charge burns uniformly in the whole engine housing, making thermal isolation of the housing wall unnecessary and allowing the space available in the engine housing to be given over entirely to the propulsive charge.

*

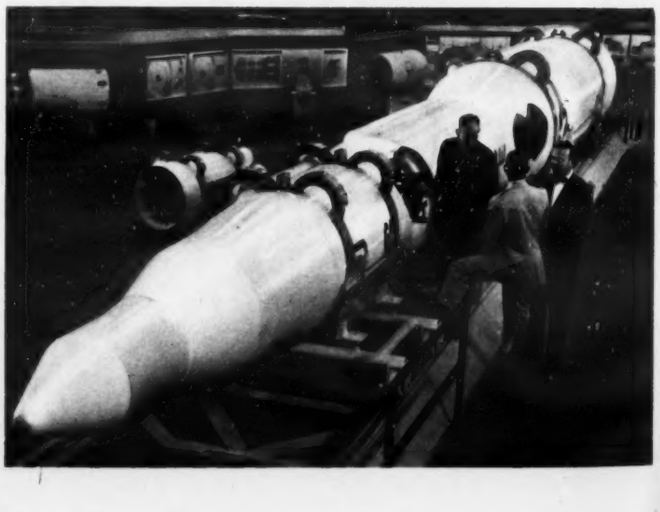
The Ballistic Missile Division of the USAF is gradually directing its main effort from ballistic weapons to manned and unmanned space vehicles. In fact, out of nineteen current programmes, only six relate to ballistic weapons (*Atlas, Titan, Minuteman, Midgetman,* an improved version of the *Polaris* and an anti-missile missile). On the other hand, the Division is already delivering booster rockets for the U.S. Navy's *Transit* navigation satellite, the *Tiros* meteorological satellite, the *Advent* and *Courrier* communications satellites as well as for the FLAG communications satellite system and the *Dyna Soar* space glider. Finally the Ballistic Missile Division has been commissioned to direct the *Discoverer, Midas* and *Samos* satellite programmes. The USAF has moreover applied for the first credits in respect of the development of a manned aerospace-plane to take off with its own power, go into space, return to earth and land. The project covering a strategic low-altitude orbital bomber with global range is at present under examination (Specification SR 79821), and there is a further project covering a strategic high altitude bomber. It is understood that this space vehicle designed for a three-man crew will be followed by the positive control bombardment system project, under Specification SR-199, a system which would have to take over the tasks at present allocated to Strategic Air Command's flying headquarters.

The projects mentioned here show that the USAF intends to rely on a new strategical concept, namely massive retaliation with mixed formations of missiles and space bombers. The view now taken is clearly that retaliation limited to the destruction of individual towns and armament centres may not hit the potential enemy in the right place and in any case would not prevent him from launching an all-embracing attack. Besides, space bombers on constant patrol could be recalled, the instantly launchable unmanned missiles being used only if this were dictated by the political and strategic situation.

*

In late 1962, the first of more than 100 *Minuteman* trains will be operational, and eighteen months later hundreds of Boeing B-52G and H jet bombers should be receiving their *Skybolt* rockets. The USA will then have at its disposal on land, sea and in the air a retaliation force composed of thousands of missiles, equal to any conceivable hostile threat and leaving further time in hand for disarmament negotiations. This gain of time is really the decisive factor for, paradoxically enough, once atomic rockets have to be launched, they have failed in their purpose. ←←

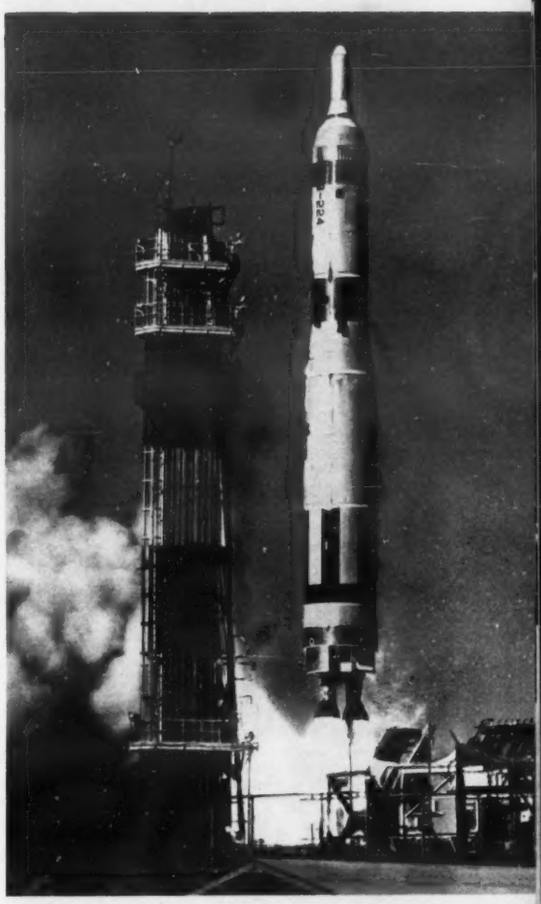
Comparison of the *Atlas* (left) and *Minuteman* (right) shows that the third generation ICBMs have been put through a severe course of slimming, the main features of which were a reduction in size of the inertial control system, improvements in the specific impulse of the solid propellants and in the weight ratio of the whole rocket and, above all, a reduction in the weight of the explosive head. This does not of course have the same explosive power as those of *Titan* and *Atlas*.



Sentinels of Security

A Report on the USAF Ballistic Missile Program

By Colonel Carlo R. Tosti, USAF, Washington, D.C.



Launching of the *Titan* SM-68 ICBM with a new Avco Mark 4 nose cone. This cone, which carries the largest nuclear warhead at present in full production, ablates during re-entry.

Today the world stands at another crossroad in history. Peace is the universal desire—yet war is the universal danger.

In the battle for peace, the ballistic missiles: the *Thor*, which is already deployed in the United Kingdom, the *Atlas*, which is in operation in small but growing numbers, the *Titan* and the *Minuteman* will stand as sentinels of security.

Yet, for all the progress which has been made, we have been disturbed in recent months by news of delays in the *Atlas* intercontinental ballistic missile program. Many have asked, I'm sure, "How serious are these delays?" "Why did they occur?" "What has been done to get back on schedule?" "How good are our ballistic missiles?"

I shall try to answer these questions for you and to put into perspective the picture of progress in the USAF ballistic missile program—particularly as it applies to the *Atlas*, the first of the large 5,500 nautical mile intercontinental ballistic missiles to come into operational status.

The American public and its friends around the world have been disturbed, indeed alarmed, by reports that the United States Air Force has fallen behind in its schedule to field operational *Atlas* intercontinental ballistic missiles. That this program has lagged in its initial phase is true to a certain degree and is cause for concern, since each ICBM on alert adds materially to the deterrent posture of the United States and its allies and serves directly the interests of world peace and security. These delays to date have not, in my opinion, critically affected the deterrent posture of United States military forces, because our major reliance today is on aircraft weapon systems like the B-52. Such delays as have been encountered in the past will be much more serious should they occur with the greater numbers of ICBM weapons programmed for activation in the future.

The examination of the problems of activating *Atlas* operational squadrons has had immediate as well as long-term benefits: attention has been focused on solving the various problems associated with the task; top management support has been marshalled within the Air Force and industry; and wider Air Force participation in the program has resulted. Today, four major commands work in close unison to bring ballistic missiles to operational status on schedule:

- the Air Research and Development Command (the developer);
- the Air Materiel Command (the producer and site activator);
- the Air Training Command (the educator of qualified manpower); and
- the Strategic Air Command (the operator).

The concerted efforts evolving from early difficulties have paid off. The first squadron at Warren AFB, Wyoming, is now fully operational, having reached this status earlier than was originally anticipated.

This fact, however, is not sufficient to put into complete perspective the state of the overall Air Force ballistic missile program.

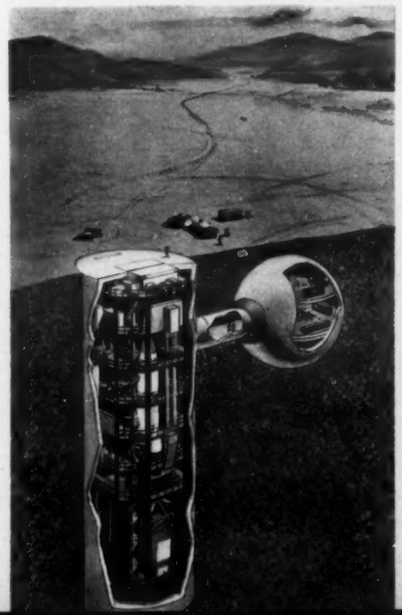
Original technical objectives

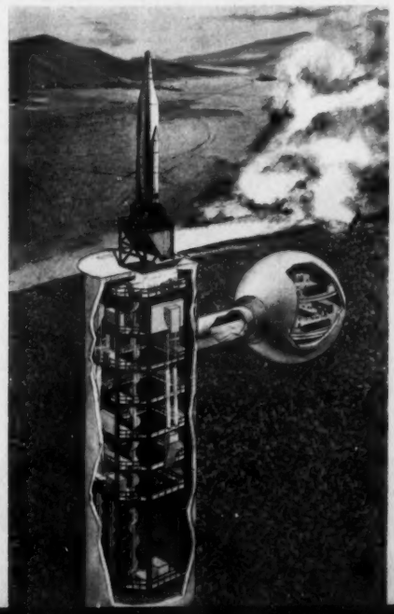
The year 1954 was a year of major technological and military decision and, perhaps, one of the most important in its implications for our future security. First, the nuclear breakthrough (the hydrogen bomb detonated in the Pacific) demonstrated great explosive power in a small compact package—a payload which by size and weight could be economically delivered by a ballistic missile. Also, encouraging progress was recorded during that period in the development of large rocket engines and inertial-type guidance systems —developments which were demonstrated in programs for the *Navaho* and *Snark* intercontinental missiles of the aerodynamic type. Consequently, leading scientists, such as Dr. John Von Neuman, and Air Force technical leaders, such as Lieutenant General Thomas S. Power and Brigadier General Bernard A. Schriever, visualized the intercontinental ballistic missile as a technically and economically feasible weapon. Further, at that time, such a weapon, with its re-entry speeds of about 15,000 m.p.h., seemed to be proof against defensive action. The implementation of this revolutionary weapon concept brought into being the *Atlas* ICBM development program—to be followed later by the *Thor* intermediate range ballistic missile and the *Titan* and *Minuteman* ICBM programs.

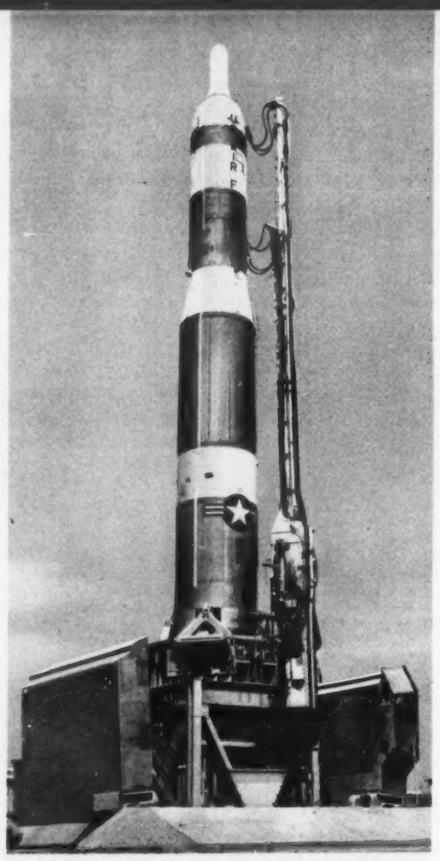
The original objective of the *Atlas* program was to develop a weapon with an intercontinental range of 5,500 n.m., an accuracy of several miles and a nuclear warhead which, although relatively small by present standards, would be many times more powerful than the nuclear weapon which devastated Hiroshima in 1945.

Remarkably, in the relatively short period of six years, these initial technical performance objectives have been surpassed in practically all respects. For example, while range was stipulated at 5,500 n.m. (6,300 statute miles), a long-range flight of about 9,000 statute miles from Cape Canaveral, beyond the southern tip of Africa into the Indian Ocean, was performed last year. Further, accuracy has far surpassed the several miles stipulated in 1954, as demonstrated by the

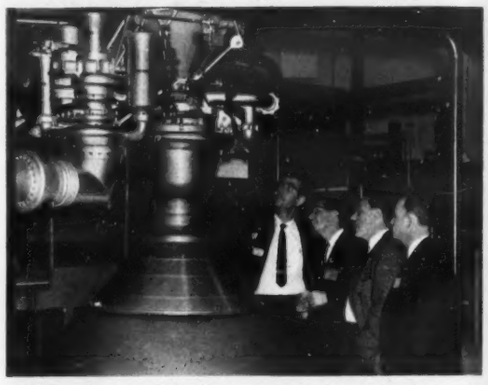
Underground launching silo with test centre for the *Atlas* ICBM. Operational pre-launch testing as well as fuelling are carried out inside the shelter (left), sunk 180 ft into the ground. Immediately before launch, a gigantic elevator brings the rocket, resting on its launching platform, to the surface, where the engines are instantly ignited.







After final operational tests, an elevator raises the *Titan*, resting on its launch platform, to ground level, where the final signal to launch is awaited. The silo cover, comprising two concrete slabs and weighing some 440,000 lb, can here be seen open.



USAF officers and leading engineers from Aerojet-General Corp. inspect full-size mockups of the first and second stage engine units of the *Titan 2*. Of interest is the large aperture angle of the thrust jet in the second stage engine (below). Compared with earlier designs for *Titan 1*, both engines exhibit simplification of the fuel pumps and of the steering mechanism, thus achieving a considerably increased thrust/weight ratio.

many recoveries of data cassettes and re-entry vehicles on the intercontinental range; at the same time, warhead explosive power has greatly increased.

But this is not all. The *Atlas* weapon system, which now is operational at Vandenberg AFB and Warren AFB, is one which can be maintained by fewer airmen more easily and with less down time, and which can react in minutes for launch, rather than several hours as conceived in 1954. I shall discuss this point at greater length later on.

Later *Atlas* series will be emplaced in hardened and dispersed sites, greatly complicating the targeting problem of an enemy and requiring the allocation, on his part, of many more weapons to insure destruction of the emplaced *Atlas* force if he hoped to strike with impunity.

All in all, therefore, the force of *Atlas* missiles to be fielded in the next two years, combined with the *Titan* ICBM forces and later the large number of compact solid-propellant *Minuteman* missiles in both fixed and mobile launchers, together with the existing force of manned aircraft weapon systems, should prove to be an effective deterrent to nuclear attack.

The site activation task

So much for future prospects. Now let's talk about the present.

The task of bringing a ballistic missile to operational status is quite different from that associated with an aircraft weapon system. With a conventional aircraft weapon system like the B-52 or F-105, all essential elements become airborne with the airplane. With a ballistic missile system, however, vital elements remain on the ground as part of the fixed installation. While an airplane can operate from many different airfields, the ICBM requires its own individual custom-tailored ground environment. It is important, therefore, to establish a clear understanding of what factors comprise the site activation task.

The task begins with an architect/engineer design of the facility to house the weapon. This is followed by construction of the facility. Simultaneously, detailed planning by the integrating and associate contractors is necessary to develop the bill of materials, the installation work flow and manloading to effectively accomplish the installation and checkout of the weapon. This plan must insure the delivery of ground support and ground operating equipment phased to construction requirements. With construction completion, the critical phases of installation, verification and demonstration of the sub-systems by themselves and finally as a total weapon system take place. Also involved is the provisioning of spares and modification kits and the preparation of technical manuals for the maintenance and operation of the system by crews of the Strategic Air Command. All of these phases of work, combined with placing the missile in a readiness condition, comprise the site activation operation.

Site activation difficulties

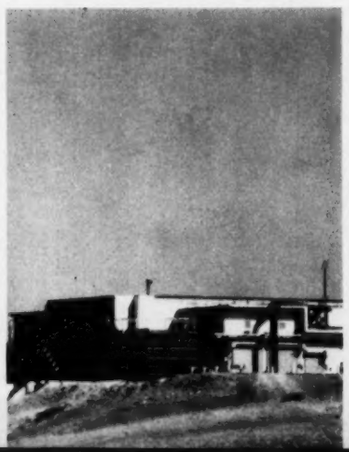
During the summer of 1960, it was apparent that difficulties were being encountered in the *Atlas* site activation program. These difficulties and the associated delays can be attributed to undertaking a vastly complex and highly technical task for the first time, while simultaneously working under the additional handicaps imposed by remote field operations, shortages of qualified personnel at these remote locations and tightly compressed time schedules. Also, these difficulties may have arisen, in part, through an over-riding preoccupation on the part of the contractor and the Air Force with solving the serious engineering problems encountered in the flight test program at the Atlantic Missile Range.

The effective response of the Air Force, the Corps of Engineers and the missile contractor to the solution of these site activation problems is evident in a review of the salient aspects of this program.

The magnitude of the site activation job is not generally understood. Site activation requires detailed planning and the establishment of a production line at each launch position. In the *Atlas* program, the highly complex and technical work of assembling and installing ground operating equipment, ground support equipment and the *Atlas* weapon itself, must be conducted at 110 individual locations.

The task at each of these locations is demanding. For one thing, the facility to house the missile is not a simple steel and concrete structure. It is a structure which must provide a fully protected environment against the blast and radiation effects

This series of pictures, taken at the Vandenberg Air Force Base, show how, within 15 minutes, the *Atlas* ICBM is erected out of its semi-hardened side by means of a cradle, fuelled with liquid oxygen and kerosene and launched at a target 6,000 miles away.



of high yield weapons. Detailed precision is required in its construction because of the close interconnection between all elements of the weapon system. Recalling that the Air Force and the Corps of Engineers worked many years to design and build high-speed refueling systems to deliver 600 gallons of fuel per minute, the current problem to deliver thousands of gallons of liquid oxygen per minute at minus 300°C is indeed a most difficult task. Not only does it involve pumping capacity, but also structural strength to absorb thermal stress. Further, all elements of the propellant system must be surgically clean, since fuel contamination may cause the system to fail.

Another factor which affects construction is time. The period of time from the go-ahead for facilities design to the required date for turnover of the completed facility to the integrating contractor is limited.

A third prime factor affecting construction is concurrency. The schedule for delivery of the several squadrons in a given weapon system configuration is very close, with the second and subsequent squadrons following closely behind the first. The normal pattern for operational readiness is to schedule squadrons at one or two month intervals. As a result, work proceeds concurrently at all squadron locations, with only a limited opportunity to pass along the full benefit of experience gained at one location to other locations that follow close behind.

Over all, however, the concept of concurrency has allowed the program to move forward swiftly and to compress the development time cycle.

As an example, consider the case of the first *Atlas* complex at Vandenberg AFB, which became operational in August 1959. The first research and development flight of the *Atlas* missile was scheduled for June 1957. This was a booster flight only, without the sustainer engine, the guidance system or the re-entry vehicle. Launch of the first operational prototype was scheduled for April 1959. Technical problems delayed attainment of the first successful operational missile flight until past mid-summer 1959. Had the philosophy of "fly before buy" been followed, facility design for the first operational squadron would have been delayed until mid-summer 1959, or later, construction being based upon flight test experience gained on the operational prototype vehicle. This would have led to the start of construction in early 1960 and completion of construction in mid-calendar year 1961. A six-month period for installation of ground support equipment and weapon system checkout would have meant that the first base would become operational in calendar year 1962 as compared with the goal of mid-calendar year 1959—in all, a 2½ year delay.

To save time, a facilities study was initiated early in 1956 based upon the contractor's initial ground support equipment configuration. Upon approval of this study in mid-1956, design of the launchers, blockhouse, and guidance station was undertaken in September 1956 and completed in May 1957. In short, facility design for the first operational complex was completed prior to the first flight of the research and development missile. Construction was completed by early fall 1958 which, incidentally, was 7 months prior to the first operational prototype flight.

The construction and activation of the first *Atlas* operational squadrons at Warren Air Force Base and Offutt Air Force Base was complicated by two major factors:

1. A prototype site (Operational Suitability Test Facility—OSTF) had not been constructed at Vandenberg Air Force Base; therefore, the sites at Warren and Offutt were the first of a kind.

2. The rapid evolutionary growth of the *Atlas* weapon system made possible greater range, higher accuracy, a bigger payload, an improved maintenance capability and greater survivability through hardening and dispersal of the missile sites.

Consequently, numerous engineering changes were incorporated into the weapon system. Each introduced changes into the sites. Each change contributed to delay and jeopardized attainment of the scheduled operational date; however, the completed site offers a greatly increased weapon system capability over the originally conceived design.

Naturally, the creation of an operational site requires a variety of highly qualified people. Obtaining qualified personnel in the numbers required to perform these precise and painstaking tasks was difficult during the initial phases of this program. The prospect of leaving a comfortable home and one's family to lead a nomadic life during peacetime is not particularly attractive. The alternative of bringing one's family to the field job is likewise unattractive because of the shortage of satisfactory housing and educational, medical and other community facilities.

Also, early in the program, management problems evolved at the operational site because of the many agencies, both inside and outside the Air Force, which have an essential role to play. Organizations outside the Air Force which participate in the site activation task are the Army Corps of Engineers, the Bureau of Public Roads, and associate contractors and sub-contractors. Unfortunately, the rapid growth and expansion of all these activities and organizations led to organizational and management deficiencies which only time and experience could bring to light.

View into the *Atlas* semi-hardened launching silo. The missile is erected after the roof opens.

Construction of an underground *Titan* site near Denver, Colorado. Dozens of *Titan* launching bases are at present under construction all over the USA, under a programme involving thousands of millions of dollars. The work of excavating the craters alone—they would be visible without difficulty from the moon through an average telescope—gives a good indication of how much the Americans are prepared to spend on their security. *Below:* the diesel engines of the power unit (under the left dome) produce more than 4,000 kW, enough to supply some 6,000 people with power and light. On the upper storey of the complex command centre (under the left dome), control officers and their staffs are at the control desks The lower floor of the command centre contains elec tronic workshops, spares stores and rest rooms. The kit chens supply hot food for the entire crew. *Above:* view of the huge air filter installation for the power unit.

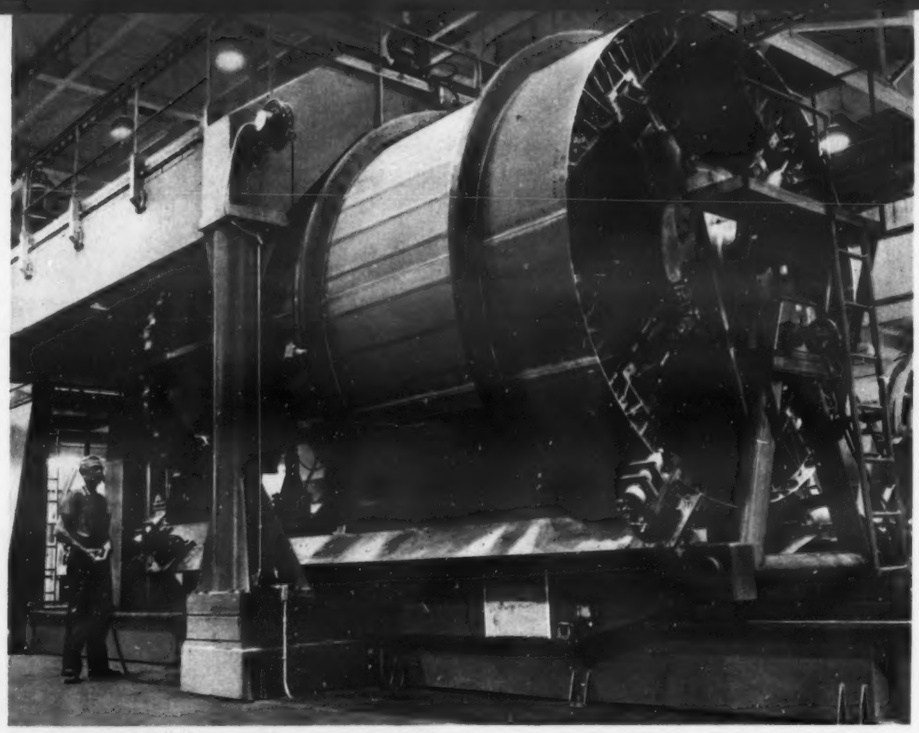
Corrective action

The problems encountered with the early *Atlas* squadrons are now understood, and measures have been taken to minimize their effect on later squadrons.

First, a prototype of the operational launcher for each new series will be built. In these prototype sites to be constructed at Vandenberg, all operational equipment will be installed, checked out and verified before the task is begun at the operational sites. This applies to *Atlas* Series E, *Titan I* and *Titan II*, and *Minuteman*. These prototypes precede the operational sites by approximately three months and will provide an essential learning period.

Moreover, each series of missiles programmed for the operational inventory is characterized by greater simplification over its predecessor. This reduction in complexity will minimize problems with future installation and checkout programs.

Another advantage is that represented by detailed production planning for installation and checkout. It was evident by October 1959 in the *Atlas* program that a fully integrated and detailed plan for executing the installation and checkout work was needed. Since installation and checkout of the Series D missiles was already so far advanced at Warren and Offutt, priority was assigned to performing complete production



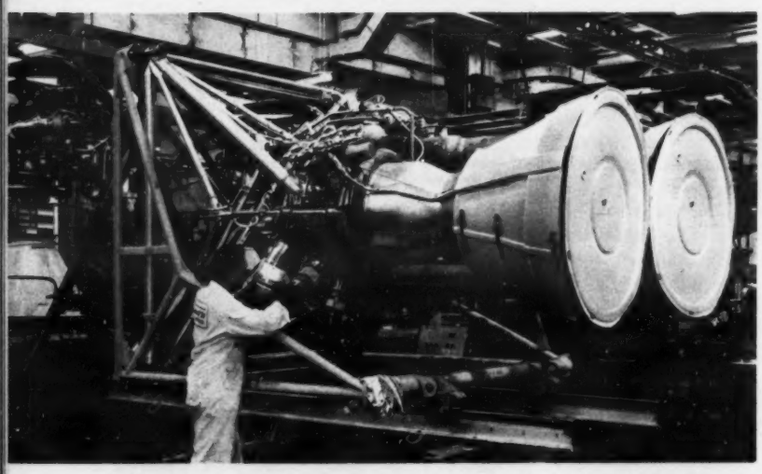
In these specially built ring frames and hydraulic jigs, the integrally reinforced plates of the *Titan* are welded into segments of the cylindrical tanks.

The Cradle of a Giant

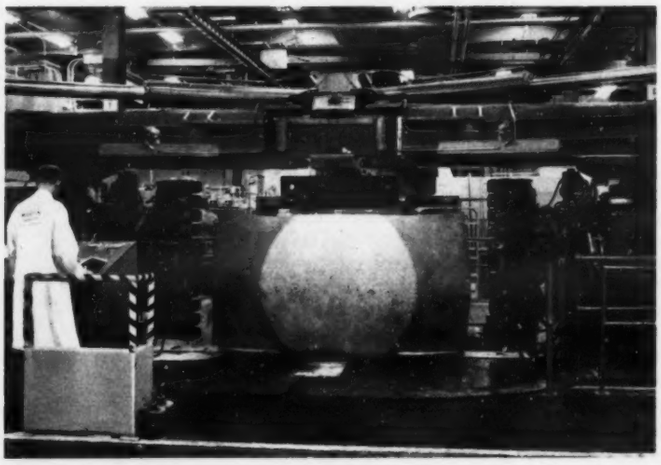
Titan Production at the Martin Company

Following President Eisenhower's personal visit to the Martin Works at Denver, Colorado, early in 1959, Major General Ben I. Funk, Head of the Inglewood Ballistic Missile Center, stated that, despite prevailing rumours, production of the *Titan* SM-68 long-range missile would not be stopped, but would in fact continue at high pressure. Subsequent developments have proved how right the General was.

Hardly a year had passed before the U.S. Department of Defense officially named Martin's Chairman, George M. Bunker, as General

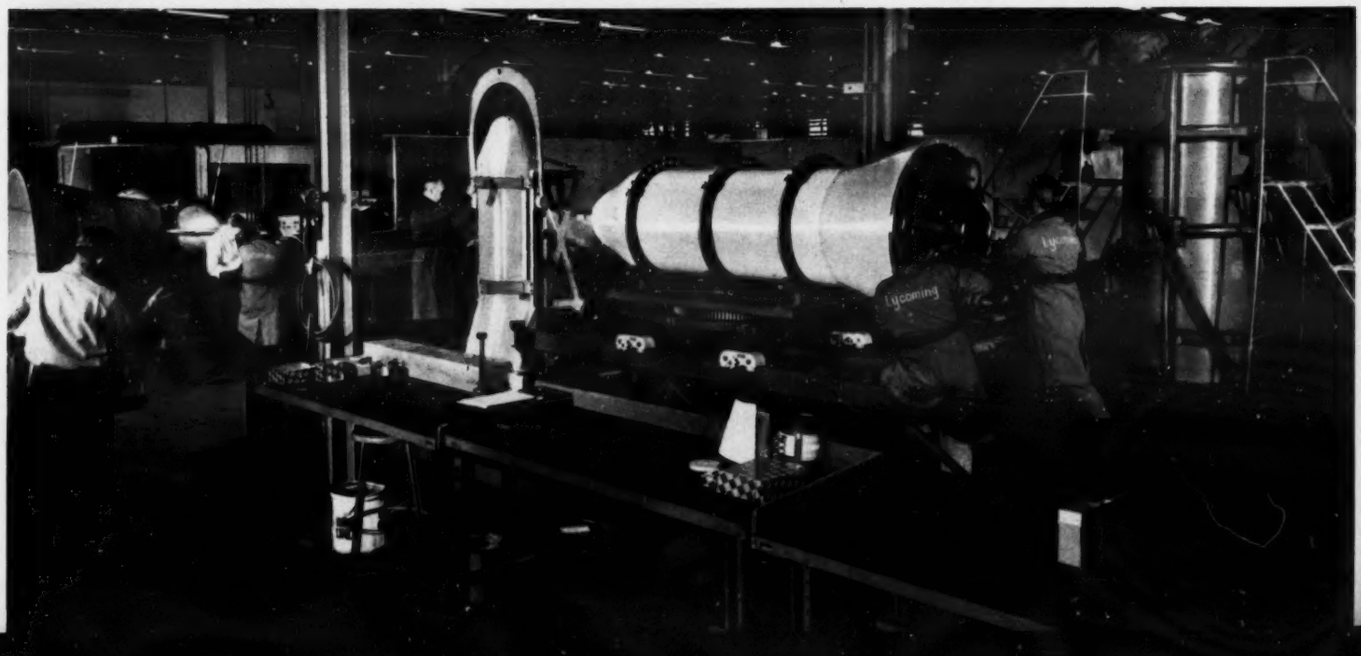


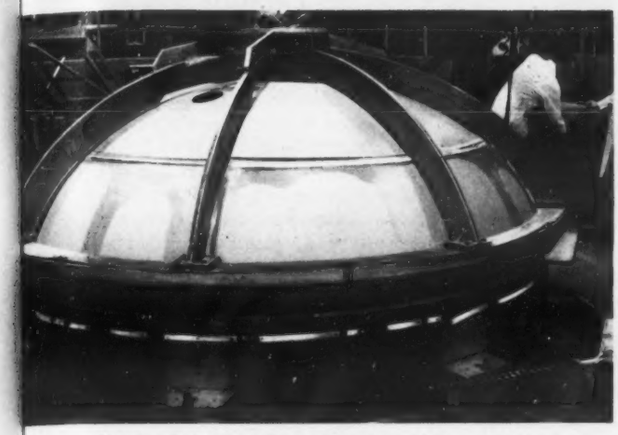
The complete first-stage *Titan* engine assembly supplied by the Aerojet-General Corp., undergoing a final check.



A metal plate for a *Titan* tank dome is formed in a Hufford stretch press.

One of the few detailed pictures of the *Titan* re-entry vehicle released by the U.S. Air Force. The Avco Corporation's Research and Advanced Development Division, Wilmington, Mass., was responsible for the design. This photo shows the RVX-3 and RVX-4 in final assembly at the Stratford, Conn., works of Avco's Lycoming Division.

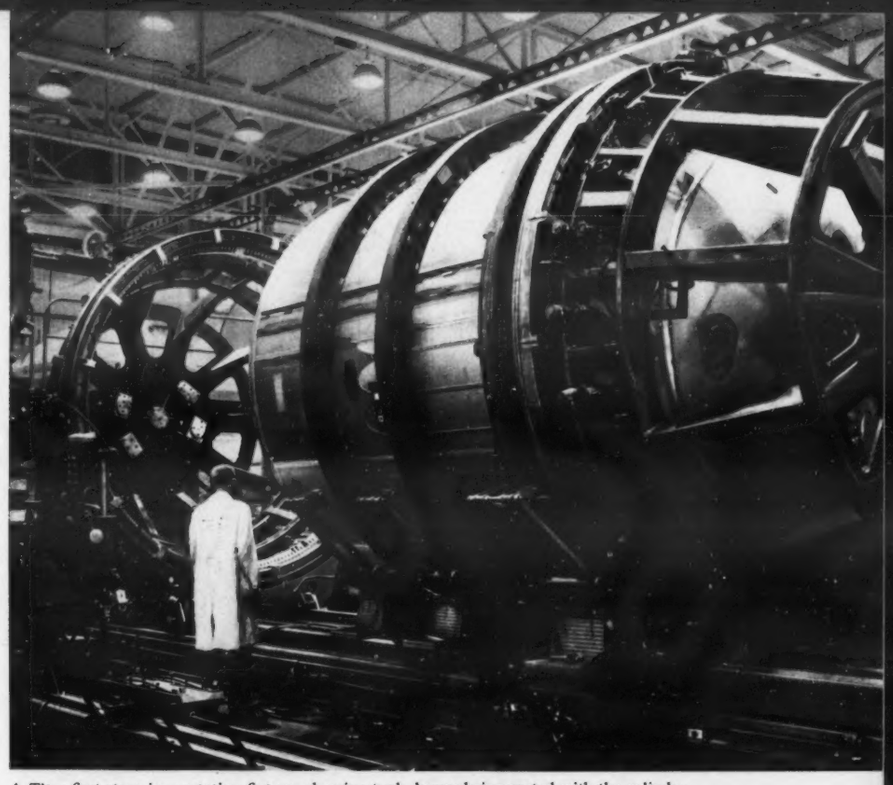




This installation is used to weld sections of the tank domes.

Manager of the *Titan* programme, so that both production and testing of this ICBM were concentrated in his hands. Today, tunnelling for the construction of hardened *Titan* sites is in full swing throughout the USA.

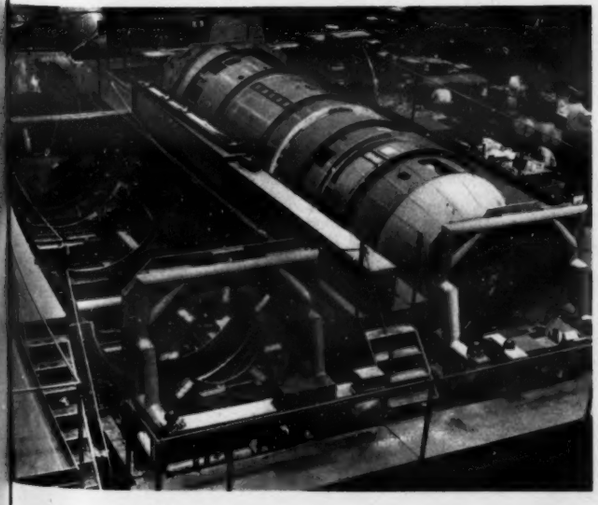
The accompanying pictures show more clearly than words the problems which Martin has had to solve in connection with the production of the *Titan*.



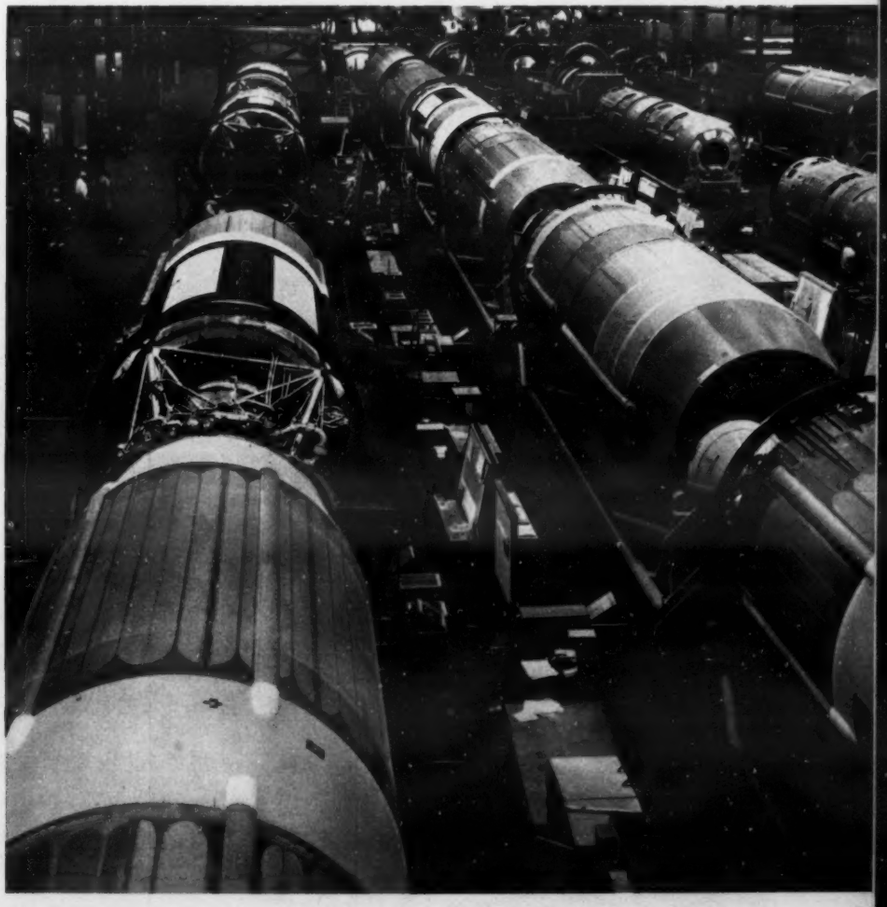
A *Titan* first stage in a rotation fixture, showing tank domes being mated with the cylinder.

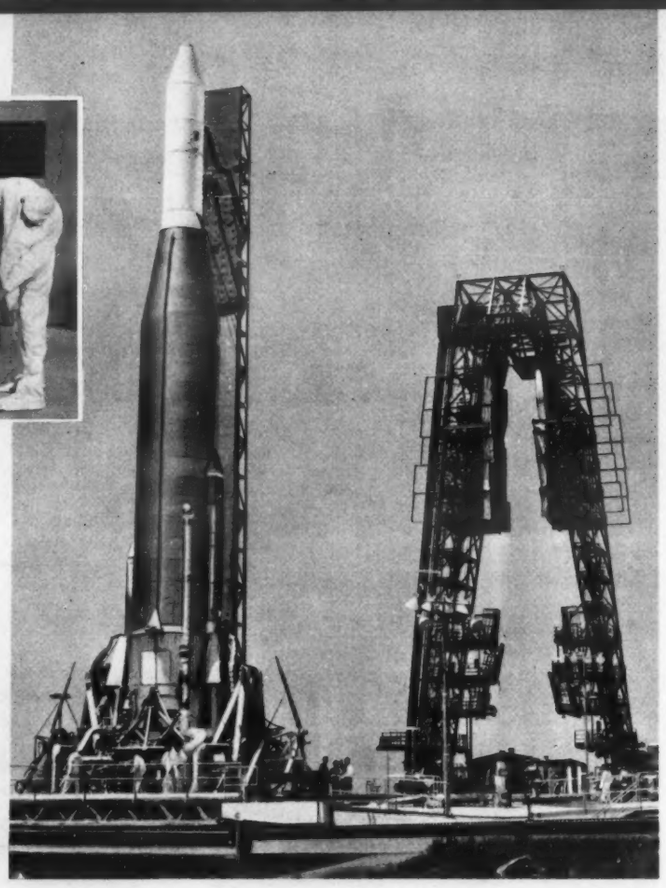
A hoist equipped with pneumatic suction cups raises an aluminium panel for the walls of the propellant tank off the bed of a Hufford stretch press, in which it was formed under 1,270 tons pressure.

The second stage splice fixture where the two tanks are fitted together with transition sections.



First and second stages of the *Titan* ICBM move down assembly lines in the Martin Company's Works at Denver.





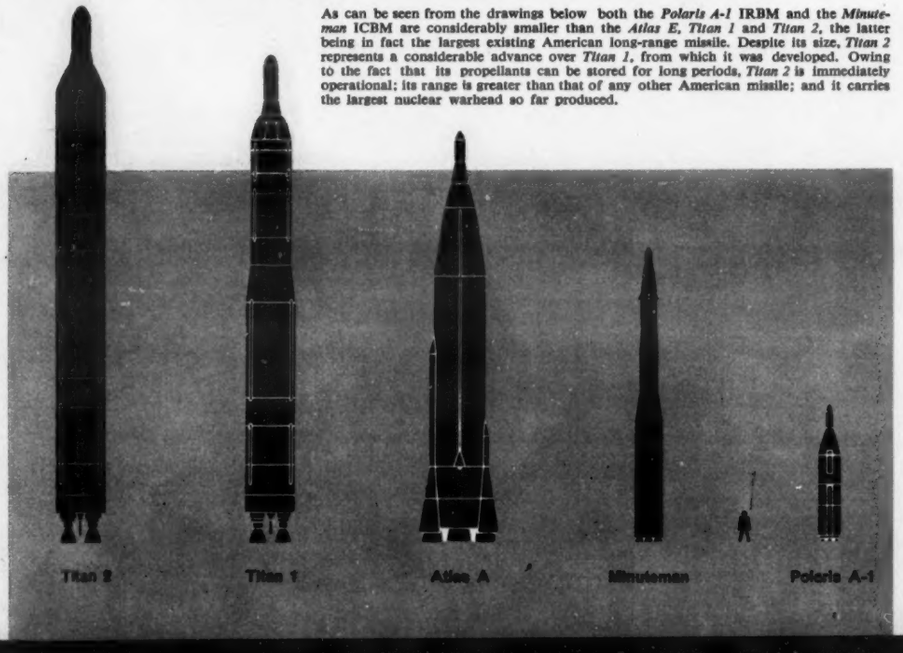
This *Atlas* booster rocket with an *Agena* second-stage is for launching the USAF's first observation satellite *Samos 1* from Point Arguello into its transpolar orbit. No. 6594 Satellite Testing Squadron of the USAF Ballistic Missile Division and Lockheed's Missiles and Space Division were commissioned to carry out these and further tests. *Left:* the *Samos* satellite. The photographic reconnaissance equipment is installed under the nose (here covered over with a cloth) and until operational must be stored with extreme care in a temperature-controlled place and under dust-free conditions; hence the protective clothing worn by the staff.

Surface-to-Surface Missiles

Designation	SM-65 Atlas D	SM-65A Atlas E	SM-68 Titan 1	SM-68B Titan 2	SM-80 Minuteman	— Polaris A-1
Main contractor	Convair	Convair	Martin	Martin	Boeing	Lockheed
Engines[1] first stage	2 Rocketdyne LR89-NA-3 LP engines	2 Rocketdyne LR89-NA-5 LP engines	1 Aerojet-General LR87-AJ-3 LP engine	1 Aerojet-General LP engine	1 Thiokol SP motor	1 Aerojet-General SP motor
second stage	1 Rocketdyne LR105-NA-3 LP engine	1 Rocketdyne LR105-NA-5 LP engine	1 Aerojet-General LR91-AJ-3 LP engine	1 Aerojet-General LP engine	1 Aerojet-General SP motor	1 Aerojet-General SP motor
third stage	—	—	—	—	1 Hercules Powder SP motor	—
Total thrust of first stage (lb)	320,000	340,000	300,000	340,000	—	—
Length (ft)	82.5	82.5	98	108	59.5	28
Launching weight (lb)	255,000	260,000	220,000	270,000	65,000	28,000
Max. range (miles)	9,000	11,500	6,300	13,000	6,330	1,380
Inertial guidance	Bosch-Arma	Bosch-Arma	AC Spark Plug	AC Spark Plug	Autonetics	MIT
Nose cone	GE Mk.3	GE Mk.3	Avco Mk.4	GE Mk.6	Avco	Lockheed/ NASA
Explosive force of nuclear warhead (megatons)[2]	3	3	4	5	2	0.5

[1] SP = solid propellant; LP = liquid propellant; [2] according to unconfirmed reports

As can be seen from the drawings below both the *Polaris A-1* IRBM and the *Minuteman* ICBM are considerably smaller than the *Atlas E*, *Titan 1* and *Titan 2*, the latter being in fact the largest existing American long-range missile. Despite its size, *Titan 2* represents a considerable advance over *Titan 1*, from which it was developed. Owing to the fact that its propellants can be stored for long periods, *Titan 2* is immediately operational; its range is greater than that of any other American missile; and it carries the largest nuclear warhead so far produced.



planning, starting with the Fairchild Squadron equipped with the new Series E missiles.

Looking to the other ICBMs, the Martin Company has prepared and is carrying out a fine site activation plan for *Titan*. The Boeing Airplane Company appears to have done an excellent planning job for the *Minuteman*. Such planning is essential to the site activation operation and includes supporting plans which are prepared for timely and adequate support in purchasing, engineering assistance, production and spares delivery.

In regard to the comment about the simplification of future ICBM weapon system installations, current plans also contemplate more and more of the highly technical electronic assembly work being accomplished under controlled factory conditions at the plant, with less and less component assembly and detailed installation work to be accomplished in the field. This should minimize problems associated with the shortage of adequate numbers of qualified technicians at remote field locations.

A major benefit, of course, will come from experience. Project Emily for the deployment of Air Force *Thor* missiles in the United Kingdom got off to a poor start for reasons similar to those of the *Atlas* program. In this case, the first *Thor* squadron of 15 missiles was four to six months late; however, the fourth and last squadron met the schedule.

Quite important, also, to the orderly management of site activation was the action taken by the Air Force to make one command and one commander responsible from the inception to the completion of a site, thus more clearly delineating the responsibilities of the many Air Force units involved at any particular site. Today, the Air Materiel Command is responsible for site activation. Major General T.P. Gerrity has been named Commander of the Ballistic Missile Center in Los Angeles and has been devoting his energies forcefully to the accomplishment of this task.

The Army's Corps of Engineers, which acts as the construction agency for the Air Force, has also taken major steps to permit it to serve more fully and more quickly the needs of this vital program. Brigadier General A. C. Welling has recently been placed in command of the Corps of Engineers Ballistic Missile Construction Office, and that office is being augmented by a large number of highly qualified and experienced engineers.

Improved Operational Capability

To this point I've discussed largely the negative aspects of the Atlas site activation story. But how about the overall picture of the missile, its present operational availability and its operational capability?

The *Atlas* is now operational at Vandenberg AFB and Warren AFB. It will deliver a larger warhead over a longer range and with a greater accuracy than anticipated about six years ago when the program was initiated. It has a reaction time of minutes as compared to the several hours visualized several years ago, and is much easier to maintain than anticipated.

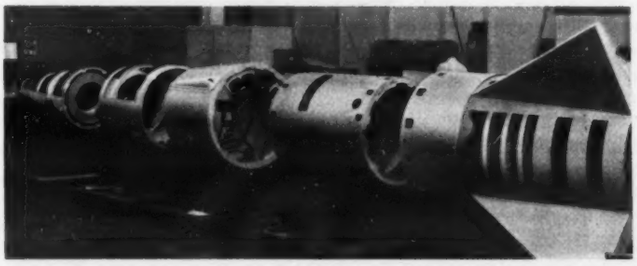
These latter two factors deserve amplification since they represent a significantly greater operational capability in the hands of the Strategic Air Command. This was made possible by electronics—in this case a system known as APChE—Automatic Programmed Checkout Equipment.

On its special launcher at the U.S. Army's White Sands, New Mexico missile range, the *Nike-Zeus* anti-missile missile is joined to the launch booster (partly concealed in picture). The booster gives a launch thrust of more than 440,000 lb.

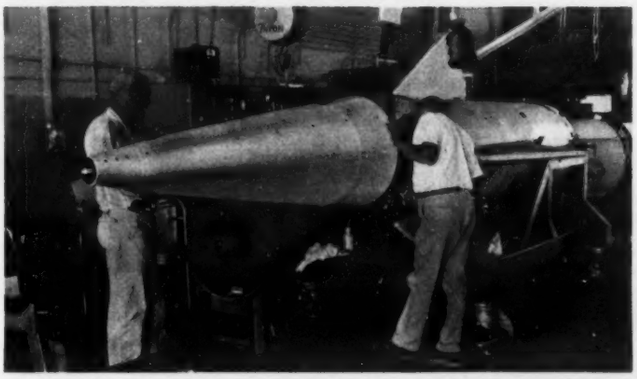
Nike-Zeus

Billions of Dollars for Anti-Missile Missiles

Western Electric, Bell Telephone Laboratories and Douglas Aircraft, under the leadership of the Army Rocket and Guided Missile Agency, have now brought the *Nike-Zeus* anti-missile missile to an advanced stage of development. The brunt is, however, borne by Sperry and RCA as main subcontractors for the complex electronic equipment; both of them have received substantial orders for long-range target and missile tracking radar of unusually high transmission power and discrimination. Experts are nevertheless far from unanimous about the chances of success for this type of defence system, in which the anti-missile missile is simply guided on a pre-calculated path into the vicinity of a hostile nose cone which is moving in at meteoric speed. The *Zeus* project has however yielded notable achievements in the field of signal and control techniques which should facilitate further developments along these lines. A *Nike-Zeus* launching base, complete with control centre, detection radar, and numerous ancillary buildings, is now springing up on the small Pacific atoll of Kwajalein, from which *Zeus* firing tests are expected to be made to intercept *Atlas* long-range rockets launched from Vandenberg Air Force Base.

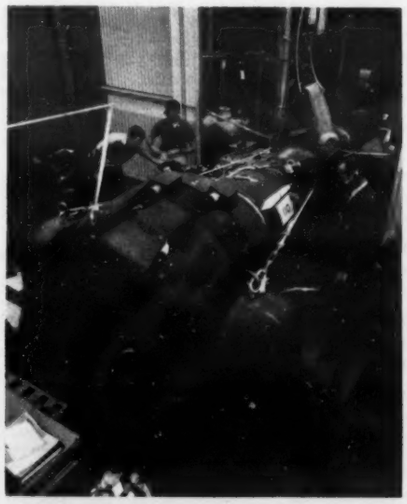


Mockup of the most important sections of the *Nike-Zeus* airframe. The picture shows, from left to right: the nose cone, which contains the servo system for the four cruciform control surfaces; the casing of the atomic warhead and of the control system (the latter with four pressure-gas nozzles for control in the ballistic phase); and the casings for the main rocket engine with four stabilization surfaces.



Engineers of the White Sands Missile Range, New Mexico, attach the nuclear warhead of a *Nike-Zeus* to the rest of the missile.

In this special vibration test rig of the Douglas Aircraft Co. at El Segundo, the whole nose section of the *Nike-Zeus*, including atomic warhead, has been subjected to rigorous vibration tests which revealed that the control, guidance and electronic systems on board the missile work satisfactorily under all conditions. Airframe vibration caused by the rocket motor constitutes a severe problem in all guided missiles.



The advantages of APChE as compared to manual checkout are summarized below:

	APChE	Manual
1. Missile Test	8 hours down time 50 manhours 6 men required—average skills	40 hours down time 600 manhours 15 men required all highly skilled
2. Results	Instantaneously available	Data reduction required
3. Total Systems Test (Missile and GSE)	100 manhours	1,600 manhours (estimated)

Future Prospects

The prospects of meeting the scheduled operational dates for future missile squadrons are very promising, although it would be impossible to insure meeting them exactly because weather and other problems outside the control of the Air Force and its contractors are always potential threats to meeting schedules.

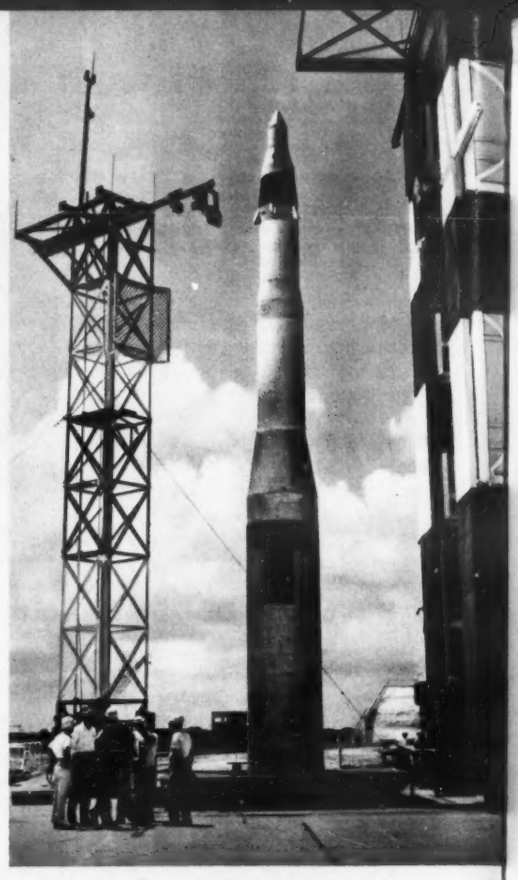
In about five years, an extensive and highly effective force of *Atlas*, *Titan* and *Minuteman* intercontinental ballistic missile weapon systems will be deployed in hardened and dispersed sites within the continental United States. This fixed force augmented by *Minuteman* on mobile railroad launchers, and the *Thor* and *Jupiter* intermediate range ballistic missiles deployed in Europe, will represent a formidable missile force.

Before closing, however, let us consider the place of the guided missile in the overall Air Force plan. The ICBM offers a highly survivable, quick reaction weapon system. Once launched, however, it cannot be recalled, nor can its target be changed. For the foreseeable future, therefore, manned weapon systems will be a major part of the aerospace force of the United States. In the more distant future, manned systems deriving from the *Dyna-Soar* program offer the quick response of ballistic missiles in combination with the recall and flexibility characteristics of manned systems. ◆◆

Strategic missiles

The Minuteman

The Mobilization Programme for a Thousand Minutemen



Only a few months after the development of the *Atlas* and *Titan* ICBMs had started, the far-seeing U.S. Air Force planners began to look for new "follow-up" designs. Even if nothing was said officially, there could be no doubt that there was intense effort in the Soviet Union to produce long-range rockets. In the absence of any prospect of reliable defence against these supersonic weapons, for it is only now that any promising means of defence are beginning to take shape, the only course open to a nation unreservedly committed to a defensive policy was to rely on the threat of mass retaliation. Such a threat can remain effective only as long as the weapons are adequately protected against surprise attack. "Adequately" does not of course imply total protection, as technically this would be hardly possible and economically certainly indefensible. The paramount object is to ensure the survival of an adequate number of retaliation weapons for a destructive counter-blow. On this score the liquid-propellant rocket, inseparable from its static as well as highly complex and expensive installations, is distinctly unsatisfactory.

The decisive factor in evaluating a strategic weapon is how much effort it compels the aggressor to divert to the task of neutralizing the reprisal threat. Only when this task is beyond the aggressor's technical and economic resources is the defender's security guaranteed, always provided that the risk of being destroyed himself is enough to restrain the potential aggressor from making an atomic attack.

In the end, therefore, all depends on how many ICBMs the attacker would have to launch simultaneously in order to be able in all probability to neutralize a counter-blow; this figure would be determined on the one hand by the destructive power and accuracy of the aggressor's weapons and on the other by the protection measures adopted by the defender. It is undeniable that the hardening of the static rocket launching sites considerably increases the effort required for their destruction. On the other hand there is no doubt that the Soviet Union is also making tremendous progress in the field of ballistic rockets and in particular their guidance. Only if the weapons of retaliation are, by their continuous mobility, removed from the danger of total destruction in a surprise attack, can strategic balance be achieved without excessive economic sacrifice.

In 1955, these and similar considerations led General Bernard A. Schriever, then Head of the Western Development Division, later Ballistic Missile Division, of the Air Research and Development Command, to order investigation of the possibility of developing solid-propellant rockets of intercontinental range. Such rockets are not only considerably simpler in construction than liquid-propellant types but also store well and need little handling and maintenance. Moreover, solid-propellant engines can start in seconds. In 1955, however, there was no experience of sufficiently powerful solid-propellant engines: stability of combustion, thrust vector control, burnout timing, and protection of combustion chamber walls from excessive heat are only some of the problems with which the few firms and experts who had already been concerned with solid-propellant rockets saw themselves confronted. But after two years of intensive study it was agreed that the technical problems were capable of solution and, on the strength of this, in 1957 the Air Research and Development Command laid down its broad requirement for a "second generation" ICBM, namely a range of 5,500 n.m.; launching from hardened launching pits or rail cars; three stages; solid propellant; storability several months and, if possible, much more; thrust vector control with swivelling jets; and inertial guidance. The project was called SM-80 *Minuteman*, after the militia who fought with the regulars in the American civil war. Khrushchev's announcement in 1957 that the USSR possessed ballistic rockets with a range of 3,750 to 4,400 miles underlined the urgency of the SM-80 project at the psychological moment, and the necessary finance, estimated in billions of dollars, was readily sanctioned by the politicians. In October 1958, the Boeing Airplane Company's Aero-Space Division was chosen as the main contractor, responsible for coordinating the project as well as for final assembly, testing, and equipment of the launching ramps. Thanks to continuing financial support on a generous scale, to excellent cooperation of the sub-contractors and especially to the unexpectedly smooth progress of the test programme, the project was completed ahead of time. Instead of in 1963 or 1964 as originally planned, the first static *Minuteman* squadron, comprising about 50 ICBMs in hardened sites, will probably be operational by summer 1962 and the first "live" missile train six months later.

For flight-testing the *Minuteman* SM-80, complete launching installations were set up on Cape Canaveral. In the foreground is one of the two 90 ft deep launching silos, with 6 ft thick walls. Behind, half hidden by the maintenance tower, can be seen the above-ground launch platform. The control and monitoring posts are located inside the two domed shelters which, with their three feet of sandbagging, closely resemble beehives.

Silo launching

To all those responsible, it was clear from the first that immediate launch readiness at low cost can be achieved only by launching the ballistic missile direct from its silo. In thousands of trials

with scale models the flow of combustion gases was simulated, first on "cold" models with pressure gas jets and later on live models, in order to study the weapon's heat, pressure and vibration characteristics at time of launch. It was originally feared that U-shaped or W-shaped pits would be necessary to allow the combustion gases to escape freely, but the tests with models showed that a simple vertical pit is sufficient. Only the optimum shape and measurements of the pit remained to be determined, for which purpose a series of 18 tests was started, using full size prototypes. The fuel supply was metered for a few seconds combustion period, just enough to lift the rocket a few hundred feet above ground level, nylon ropes being used to prevent the rocket falling back into the pit. The first attempt of this kind was on September 15th, 1959 at Edwards Air Force Base in California. Further tests followed and were so successful that in May 1960, after the eighth test, the Air Force announced the major problems solved, and the remaining tests were not proceeded with. This meant a saving of $10 million as well as of nearly a whole year.

Launching installations, built on Cape Canaveral at a cost of $7 million, included two surface launching platforms, two 90 ft launching silos (nearly 26 ft inside diameter), two assembly towers, two shelters, and various auxiliary buildings. The first launching of a *Minuteman* with all three stages firing took place on February 1st, 1961 from an above-ground platform when, as far as known, the re-entry vehicle reached the target area. Later on, launchings from silos and railway trucks are expected to be carried out at Cape Canaveral.

A few weeks ago, work started in the vicinity of Malmstrom Air Force Base, Utah, on the erection of 150 launching silos with control centres, completion of which is expected in 15 to 18 months. A further three squadrons, each of 50 *Minutemen*, will be stationed in the vicinity of Ellsworth Air Force Base, South Dakota, and for a third site the Air Force is considering Pease Air Force Base near Portsmouth, New Hampshire, but the final decision depends on the results of the soil analyses now in progress.

Each launching silo will be some 85 ft deep and have an inside base diameter of 12 ft. Except for a 10-ton heavy ferro-concrete cover on a fenced-in concrete platform, nothing will be visible from outside, neither cables, personnel nor buildings. Each underground control centre commands 10 launching silos. In order to protect the crew and instruments from the excessive shocks and tremors which are inevitably felt when rockets are launched from below ground, the bunkers are cushioned. Each control centre is provided with its own oxygen, water, rations, and power supply so that the crew, presumably two men, can hold out for weeks if necessary. The silos are completely unguarded and in contact with the control centre only by the specially developed transmission system mentioned below. Several mutually independent warning installations will, however, alert the control centre, should unauthorized persons enter the launching silo area.

Each silo is provided with a cooling device to maintain the temperature and humidity in the missile area constant, also bearing in mind that the storage life of solid propellants is not unlimited even under optimum conditions. The Air Force is planning on about 3 years between overhauls, for which the missiles must be hoisted out of the silos and taken to a maintenance area. Minor inspections or replacements can be carried out *in situ*. Measurable damage occurring in course of storage is reported to the control centre by the monitoring device. This, however, requires a multi-channel data transmission system between the control centre and the launching silo, which is also necessary for pre-launching checks and launch release. Owing to the long distances, underground cables would be extremely costly ($20,000–25,000 per mile) and in any case these are not immune to electronic disturbances.

Mockup of a *Minuteman* train at Boeing's Seattle, Washington, plant. The American Machine & Foundry Co. and the American Car & Foundry Division of ACF Industries are responsible for development and construction of the rolling stock.

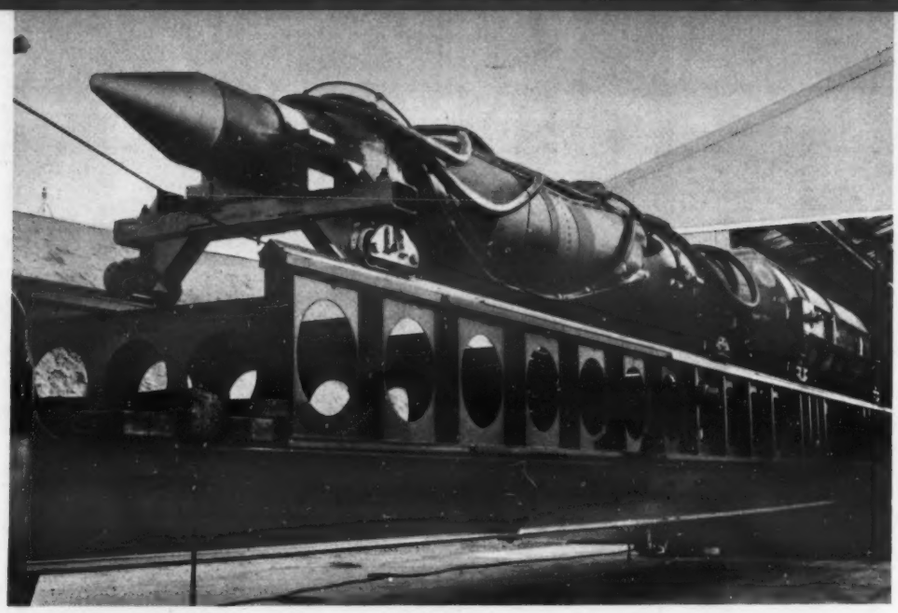
Air Research and Development Command has for years been working with Sylvania, Boeing and the U.S. Bureau of Standards to develop a transmission system taking advantage of the conductivity of the earth itself. In this system, special subterranean antennas send out electromagnetic waves, which are deflected at the earth's surface, pass along it, and are finally received by further subterranean antennas located several miles away. This method of transmission will first be used on the static sites and later perhaps on the missile trains and will, it is estimated, allow a saving of at least $300,000 per silo, or some $135 million for the three *Minuteman* bases planned at present.

Rocket engines — light construction method

Each of the three *Minuteman* stages incorporates a solid-propellant rocket engine with 4 swivelling jets for thrust vector control, which presented the engineers and metallurgists with extraordinarily difficult problems in view of the danger of nozzle erosion during the combustion period and consequent changes in the expansion ratio. Jetevators, as used in the Lockheed *Polaris*, reduce thrust and are also somewhat heavier than the swivelling type.

The first-stage engine, with thrust estimated at 60 tons, was developed by Thiokol. The propellant is a mixture of polybutadiene, acrylic acid and ammonium perchlorate, with an aluminium base additive for stabilization. The 20 ft long bodies are made of high-tensile steel rings, butt-welded together. In November, 1960 Thiokol laid the foundation stone of a new production unit, Plant

When the missile trains, here shown in model form, stop at exactly measured points on the railway network and erect their rockets, the five ICBMs are on their way within less than a minute from receipt of the order to launch. The temperature-controlled strongbacks do not open until seconds before the first stage is ignited.



At full launching weight, but with enough propellant for only a few seconds combustion period, this *Minuteman* emerges from the testing shed at Edwards Air Force Base for launching. Only eight tests, in which the missile was held by nylon ropes, were needed to fix optimum measurements for the launching silos.

No. 78, on the Great Salt Lake, for full-scale production of the *Minuteman* booster. Owing to the large size of these rocket engines, Thiokol replaced the conventional phased production by combining in one assembly pit various operations such as lining combustion chambers, inserting the fuel, drying, reworking the combustion chambers, and fitting the dome and jet assembly. The finished engines are stored under controlled temperature and then taken on special transporters to Hill Air Force Base, only 50 miles away, where the *Minuteman* is assembled. Based on its *Polaris* experience, Aerojet-General developed the second-stage engine which burns polyurethane.

The contract for the third stage was won by the Hercules Powder Co., as a result of all-out research on high energy fuels and new processes for combustion chamber manufacture. Hercules developed a two-basis propellant with very high specific impulse, ostensibly the highest yet achieved in a solid mixture. Combustion chamber temperatures were over 6,000 °F, and the fact that the new fuel is very sensitive to variation in storage temperature is hardly a disadvantage in the case of the *Minuteman*, since conditions must in any case be kept constant from the construction of the combustion chambers right up to launching.

Hercules worked for ten years on developing *Spiralloy*, an anisotropic low-weight high-stability material with the enormous advantage of cheapness. *Spiralloy* consists of spirally spun glass threads embedded in a mixture of epoxy resin and metal powder. The glass threads are continuous throughout the cylindrical and spherical parts of the casing, thus giving a uniform seamless texture and possessing the same tensile strength as the glass thread. Critical points can be easily strengthened, as desired, by the positioning of the glass threads. Special finishing is not required.

Through the simultaneous opening of a number or ports, burnout can be regulated to within a few thousandths of a second; this is of decisive importance in an intercontinental rocket, where even minor deviations from optimum burnout speed may cause the target to be missed by several miles.

Railborne Minutemen

In December, 1960, Lieutenant General Schriever officially announced the Air Force's intention to equip more than 100 railway trains as *Minuteman* sites. At the same time the first mobile *Minuteman* formation was put into service at Hill Air Force Base, Utah. This formation, Strategic Rocket Wing 4062, will, however, not receive its first two missile trains until late 1962, and the Wing will meanwhile concentrate on training personnel and merge into the general development programme.

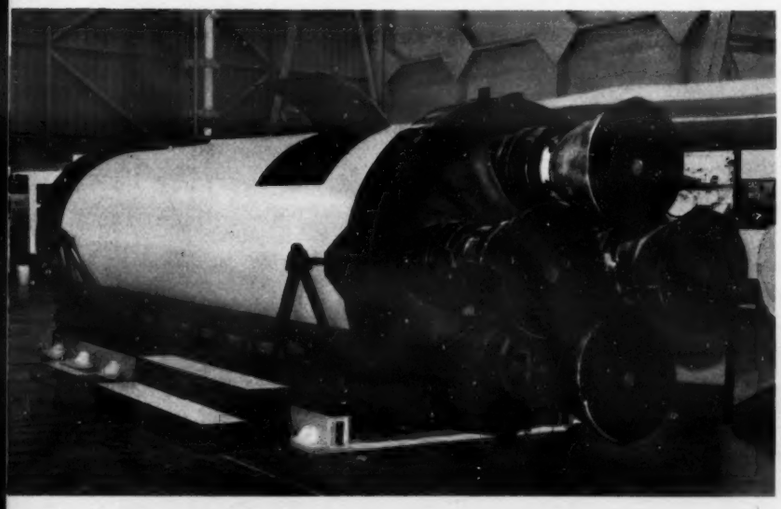
Each missile train, made up of 11 to 15 closed cars, carries three to five *Minutemen*. Whilst outwardly the railcars closely resemble normal rolling stock, a missile train would not escape a trained observer. However, it is not the intention of the Air Force to conceal or camouflage these trains, which will be deployed only on the northern half of the 220,000 mile railway system, since the range of the rockets is, at any rate for the time being, not adequate for their release from points in the Southern States.

Production and development of the six-axle missile launch car, which weighs about 300,000 lb when fully equipped and has an overall length of 88 ft, have been entrusted to two firms, American Machine & Foundry Co., and American Car & Foundry Division of ACF Industries. The first missile railcar was delivered to Boeing on January 26th.

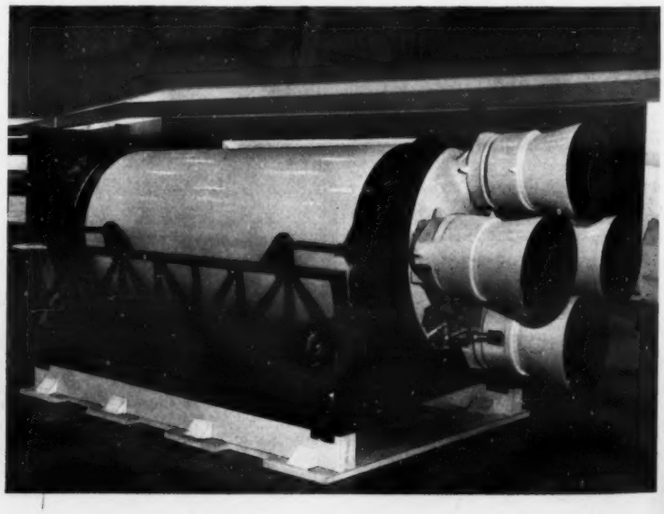
The indispensability of vibration-free storage for the missile set the engineers some difficult problems. The load is protected against shocks and vibrations in all directions. Hydraulic shock absorbers neutralize all sudden longitudinal forces, air springs maintain the car body at a constant height irrespective of the weight, and in addition to spiral springs, special compensating springs are fitted to balance the irregularities in the track.

Whilst moving on the train, the missile itself is enclosed in a temperature-controlled capsule (strongback) and held in a horizontal position on a launcher-erector. When the alert is given, the train stops, and the wheels of the missile launch car, as well as all the spring units between the chassis and the body, are locked into position. Simultaneously twelve hydraulic jacks move out to the sides, embed themselves in the gravel of the trackbed and lift the railcar slightly off the track. The roof opens, the launcher-erector moves up with the missile, places it on the launch platform

The *Minuteman's* first stage engine, developed by the Thiokol Chemical Corp. The swivelling device for the thrust jets is clearly recognizable.



With its *Polaris* experience behind it, Aerojet-General Corp. produced the second stage engine for the *Minuteman*. The propellant is polyurethane, with an aluminium base additive for stabilizing combustion.

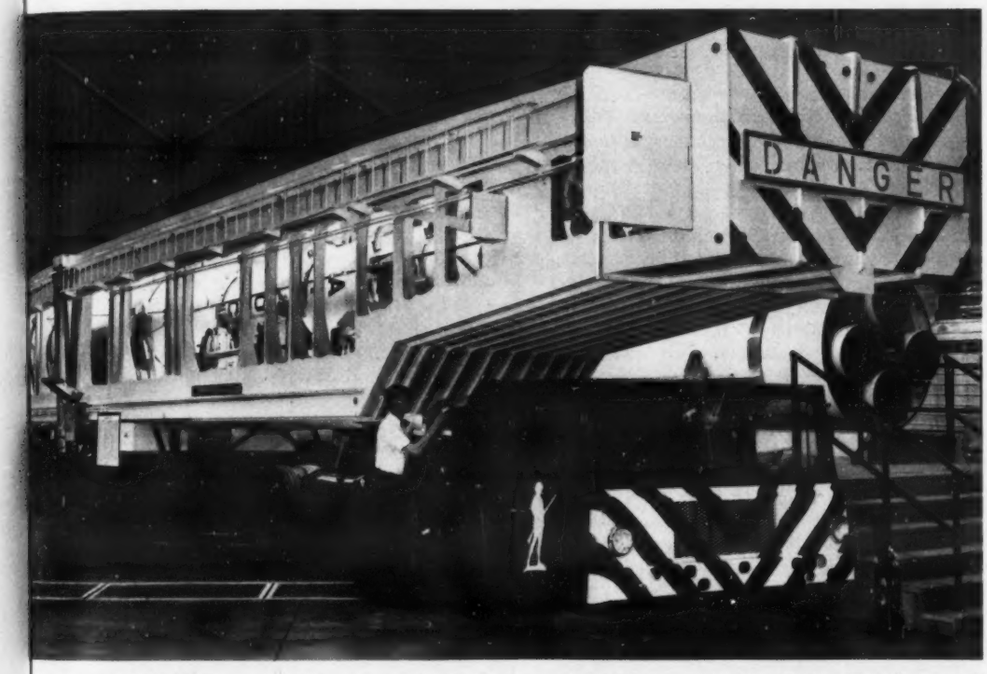


and then moves down again. The twelve independently adjustable jacks ensure that the launching ring is horizontal. Heat-deflector plates, which divert the combustion gases to both sides, are used for flame-protection of the railcar and railway track. According to Boeing, the missiles are ready for launch 15 minutes after the alert. In order to maintain conditions constant as long as possible, the strongback does not open to release the missile until the order to launch is given.

As security against arbitrary release of the missiles, two identical control desks are provided, connected in series, and all switches at both control desks must be in the right position before it is possible to launch the *Minuteman*. The control desks are adjacent but partitioned off by splinter-proof glass, with access by separate entrances. The train commander is in constant touch with Strategic Air Command's underground Headquarters by UHF and single sideband transmission. Finally, as a vital security precaution, it is intended to incorporate a system whereby a missile can be released only after receipt of a coded launching order from Strategic Air Command's underground headquarters or flying command centres.

In order to protect the launching platforms from destruction by surprise attack, it is quite unnecessary to keep the trains continually on the move. It is intended that trains will more often remain stationary at points on the railway which have been exactly measured and pre-marked, enabling the ICBM to be released within less than one minute, a timing comparable with static sites. A regular timetable is not intended, as it is precisely the unpredictability of movement offered by this system which constitutes its best protection.

The trains will return at regular intervals to supply sites, the first of which will be on Hill Air Force Base, but during the cruising period, in some cases several weeks, they will be completely self-contained. They carry food and water supplies, sleeping cars, a kitchen-dining car, and a recreation car with standby-room. The power supply comprises five generators, allowing breakdown of any three without loss of full power, and a single generator will give enough power for rocket launching. The Air Force found it preferable to use civilian engine drivers for *Minuteman* trains on account of the high cost of training military personnel and problems of integrating them with the railroad companies. The Air Force has also reached an agreement with the railway unions to ensure uninterrupted operations of *Minuteman* trains even in the event of a railway strike.



This 108,000 lb monster is for transporting the finally assembled *Minuteman* to the static launching silo or to the supply site for the missile trains, only the re-entry vehicle with its atomic warhead being moved separately. The missile is enclosed in temperature-controlled strongback (supplied by the Cessna Aircraft Corp.), and on arrival at the launching site is erected by means of the hydraulic erection system (by Bendix Pacific Division) and then lowered into the underground silo. The transporter and trailer are by the Truck and Coach Division of General Motors.

Mockup of a launching silo under critical inspection by Colonel James Foster (Ballistic Missile Center), Colonel Sam Phillips (Ballistic Missile Division) and T. A. Wilson (Boeing's *Minuteman* Programme Manager).

Probably each missile train will have its own independent locomotive, but it would also be possible to attach the train-set to regular passenger or goods trains.

Four experimental trips with a mockup train in the summer of 1960 demonstrated the compatibility of military requirements with those of civilian railway operation, allowed the train's equipment and the signals system to be tested, and threw light on climatic conditions along the railway network and the accelerations and vibrations due to train movement. No missiles were carried on these trips.

A few months ago, Lieutenant General Schriever, Commander of Air Research Command since April 1959, referred in a speech to the danger of missile trains in passage through towns and villages and affirmed that the danger to the civil population from these trains was not greater than from the thousands of petrol and oil tank cars which are carried day-in and day-out by the railways. In collision or derailment, a *Minuteman* train would at the worst cause a small explosion or a fire. He gave assurances that unintentional release of the atomic charge was out of the question owing to a reliable safety arming system, and that it was for all practical purposes impossible for the missile, once launched, to take a wrong course.

Floating Minuteman sites

Boeing and the U.S. Navy have been studying the feasibility of setting up floating launch platforms which would have two-dimensional mobility, whereas railway trains are tied to the known track network. American Machine & Foundry proposed that a few hundred out-of-date cargo vessels be equipped with *Minutemen* and cruise the oceans in a permanent state of readiness, but so far this has not met with much enthusiasm from the Air Force. The supporters of the sea idea make the point that old cargo vessels in good condition, such as Liberty and Victory class ships, can be bought cheaply, and re-equipment would be no problem. Such vessels would be an easy target for enemy submarines, but provided they were deployed in sufficient numbers (at least a few hundred), the aggressor would be obliged to employ an equal number of submarines in pursuit and also destroy them simultaneously, which seems impossible. Owing to the greater range of the *Minuteman*, the floating sites would enjoy a far larger radius of action than the *Polaris* submarine, which they could with advantage complement.

The Air Force remains, however, a strong advocate of missile trains with the weighty argument that 10,000 to 20,000 ICBMs would be required to destroy the available 100,000 mile railway network. Moreover, to be effective, any surprise attack would have to neutralize all retaliation weapons at one blow, which would entail a correspondingly large number not only of rockets but also of launching ramps. There is also the very plausible argument that the co-ordinates of the launching sites would be as well known in railway as in static sites. At present, thousands of bench marks are being put along the railway tracks to serve as reference points for the inertial guidance systems, and the guided missile trains are never more than 10 miles from an exactly measured spot. An intertial navigation system on board the train continuously calculates the train's position, even when this does not coincide with a reference point.

These pictures can do no more than hint at the enormous demands made by an ICBM weapon system in the field of electronics.
Above: A model of the control desk in a hardened command post is demonstrated to Major General O. J. Ritland, Commander of the Ballistic Missile Division, by Colonel S. Phillips, USAF Project Officer. T. A. Wilson, Manager of Boeing's *Minuteman* programme, is looking on.

Signals centre inside the control car of a missile train with UHF and single sideband transmission for intercommunication with Strategic Air Command Headquarters.

Electronics — the vital component of a modern weapon system

Two demands on rockets of intercontinental range are conflicting: on the one hand, the length of the flight path makes imperative a control system of the highest exactitude, and on the other hand, every pound of useful load is multiplied in the total weight and hence in the volume of the missile. Definite limits to the *Minuteman's* dimensions are of course set by the profile of the railway system, and from the beginning size and weight factors had to be carefully considered. Small wonder, then, that the electronic system had to be the last word in miniaturization. The Autonetics Division of North American Aviation was the main contractor for the inertial guidance system, which is fully transistorized and includes a universal computer, for use not only in guiding the missile but also in working out data for operational testing and pre-launching checks. The geographical coordinates of the target and the railborne launching ramps, as well as the calculation programme, are given and monitored by the control desk in the command centre (shelter or railcar).

The so-called Data Acquisition and Quick-Look Display System supplied by Radiation Inc., Melbourne, Florida permits visual monitoring by the control desk. The monitoring device works on the pulse modulation principle and is also used for operational testing of the missile prior to launching. All data are immediately recorded for later investigation.

Since weight and volume considerations ruled out much use of parallel systems, the highest reliability in each individual component is essential, and each contractor has worked out his own programme for improving the operational dependability of his products. Tens of thousands of production samples are often drawn at random and subjected to very severe impact, vibration, temperature variation, humidity and other tests. Since the parts tested are used in applications other than the *Minuteman*, many other customers also profit from this high standard quality control.

Delicate merchandise

A serious stretcher case would hardly be moved with more care than when the *Minuteman*, either in individual stages or complete, is transported to the assembly centres and launching sites, for solid-propellant rockets and inertial guidance systems are amongst the most delicate merchandise known.

The rocket engines must enjoy complete protection against excessive shocks, vibrations and variations in temperature and humidity and, besides being enclosed in a temperature-controlled container, each engine is mounted on a mobile torsion-sprung frame with rubber cushions. These frames are suitable for road, rail and air transport.

The transport of the 40 ft missile is a still trickier problem. Without its re-entry vehicle but with protective container, carrying frames, and some auxiliary equipment, the missile is already up to the highest permitted weight for a complete road vehicle, but special permission has been given for the legal limits to be exceeded, although only on specified roads. In order to minimize limitations on the mobility of the transport vehicles as far as possible, the existing road system was tested at bridges, underpasses, bends, and cuttings. The resulting specifications for these vehicles laid down maximum total weight per vehicle as 108,000 lb, maximum load per axle 1,800 lb, overall width 10 ft, and maximum height of load 13 ft 6 in. Other stipulations were that it must be possible to turn from a 32 ft road into a right angle crossing; that the missile container must be transportable by rail and by air; that the temperature inside the container must be maintained between 27°C and —38°C; and that the vehicle must carry its own loading equipment in order to minimize such equipment at the launch platform. The solution to this intriguing engineering problem is a 63 ft 6 in. missile container (produced by Cessna Aircraft Company) resting at the front on a four-axle transporter with 275 h.p. engine (by General Motors Truck and Body Division) and at the rear on a three-axle trailer. On arrival at destination, the hydraulic erection system (by Bendix Pacific Division) can be vertically erected above the launching silo, into which the rocket is lowered by winches. The re-entry vehicle with atomic warhead is not fitted until the missile is in the launching silo.

Costs — the decisive factor

The *Minuteman* system undeniably represents a considerable technical advance over the *Atlas* and *Titan* ICBMs, but military opinion is even more impressed by its economic advantages, which are of course again due to the technicians. Some of the figures speak for themselves: for instance the ground installations of a *Minuteman* squadron, i.e., 50 hardened sites distributed over hundreds of square miles, plus 5 hardened control centres, involve an expenditure of some $20 million, compared with at least $80 million, for a shelter for nine *Titans* concentrated in a relatively small area; in the *Minuteman* squadron, the number of men per ICBM is less than one tenth of the same figure for the *Atlas* squadron. Admittedly, however, the explosive power of the *Minuteman* is estimated at two megatons below that of the *Atlas* or *Titan*. The Air Force values the existing railway system at $35,000 million.

According to current estimates, a *Minuteman* on a hardened site costs $2.4 million and a mobile *Minuteman* on a train twice this figure. According to USAF studies, several thousand high-precision ICBMs of several megatons explosive power would be required in order to neutralize the planned three static *Minuteman* sites, and 10,000 to 20,000 in order to destroy the railway network. The *Minuteman* system costs far less than the aggressor would have to invest in its destruction or, in General Schriever's recent words, "We buy in fact the most deterrence for each dollar." ←←

Boeing has set up a rig for dynamic tests, in which the stresses on the missile from launch right through to third stage burnout can be simulated.

Hound Dog—Fangs of a Deterrent Force

By Dale D. Myers, Vice-President, Space & Information Systems Division, North American Aviation

In the American idiom, the epithet "hound dog" evokes an image of a friendly, frolicking creature whose favorite pursuits include the yapping chase of rabbit and 'coon, lazing in the sun, baying at the moon. In the parlance of the United States Air Force's Strategic Air Command, however, "Hound Dog" conveys no such quaint connotation. For this is a creature of a different and deadly breed.

Keyed to the command of retaliatory counter-attack, the SAC GAM-77 *Hound Dog* guided air-to-surface missile is one of the major deterrent forces in the defense of America.

The program from development go-ahead to production missile delivery was one of the most demanding the engineers of North American Aviation's Space and Information Systems Division/formerly the Missile Division—ever encountered. Confronted with its harsh, inflexible delivery dates, its greedy gobbling of man-hours and scientific talent, they called it as they saw it. Hence the name *Hound Dog*.

The *Hound Dog* is a high supersonic, guided air-to-surface missile armed with a devastating nuclear warhead. Forty-three feet long with a 12 ft wing span, the approximately 5 ton missile has a range of several hundred miles.

Pylon-mounted on the underwing surfaces of the B-52, the missiles are carried in pairs and are capable of neutralizing the enemy's primary defensive installations which may lie in the path of the bomber or, if necessary, can be used for the destruction of prime targets.

As the *Hound Dog* is equipped with a unique, unjammable inertial auto-navigator, its course to target impact cannot be diverted by electronic countermeasures. The B-52 navigator can alter launch point, change target, vary trajectory and select missile flight mode even after the bomber is airborne.

The *Hound Dog's* built-in anti-detection capabilities almost guarantee mission success. Prior to launch, the missile can be programmed to feint into veering pseudo-attack, complete an abrupt dogleg maneuver, then dive in to deliver its nuclear impact on a preselected target. This advantage, coupled with the missile's ability to change trajectory, negates nearly all interception countermeasures.

Powered by a Pratt & Whitney J-52 turbojet, spike-inlet engine—a scaled-down version of the B-52's J-57—the *Hound Dog* consumes the same fuel as does the bomber. This is a factor extremely important to the weapon's successful performance.

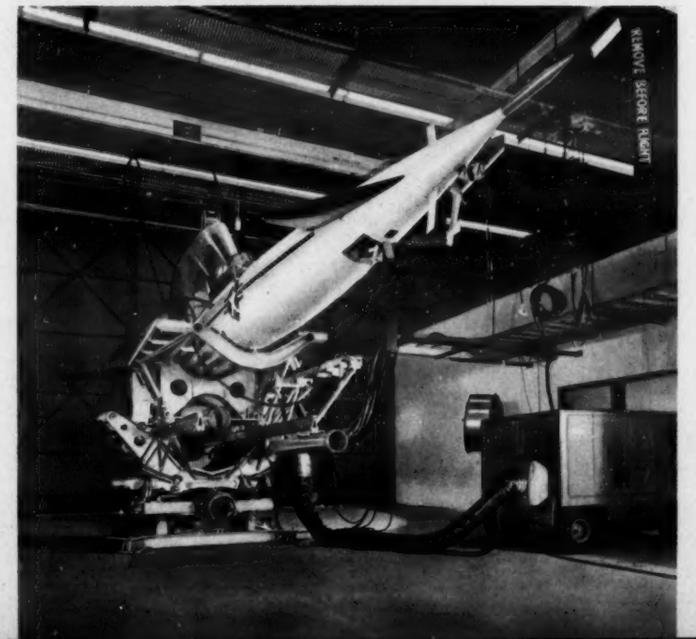
The *Hound Dog* can also be employed as an auxiliary booster during take-off and flight, significantly reducing the bomber's take-off roll. This increases the number of airfields available to SAC B-52 wings, permitting greater latitude in base deployment and greater take-off fuel loads to increase range.

The fact that missile fuel can be replenished in flight permits B-52 crews to conduct combined systems checkout procedures on the captive missile. This procedure, in conjunction with the stringent checkouts previously conducted by SAC ground personnel, provides assurance that the missile will perform as programmed. However, in the remote possibility that a malfunction does occur, the *Hound Dog* is aerodynamically designed for effective employment as a free-fall bomb.

The Strategic Air Command's B-52s are more than intercontinental bombers. They are flying missile platforms whose flexibility and state of readiness were dramatically demonstrated only recently.

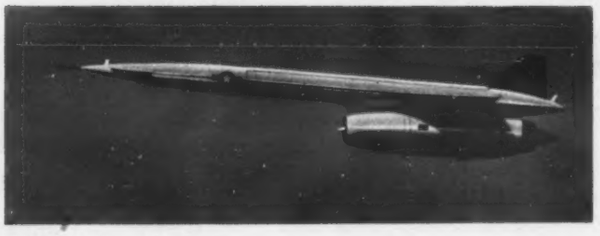
In a flight test, aptly named "Operation Blue Nose," a *Hound Dog*-equipped B-52 took off from its Florida SAC base, flew to the North Pole, returned to the Florida missile range and then successfully launched one of its *Hound Dogs*. The missile was subjected to various altitude stresses

The GAM-77 *Hound Dog* on a special test rig of North American's Space and Information Systems Division, Downey, California. Here all of the missile's systems are subjected to rigorous operational tests.



A *Hound Dog* being loaded into a Douglas C-124 military transport at Long Beach airfield for ferrying to Eglin AFB, Florida.

North American technicians carrying out maintenance work on the special mount for suspending the GAM-77 under the wing of the carrier aircraft. The mount on the front portion of the missile's fuselage (right) carries the electronic equipment and parts of the inertial guidance system.



GAM-77 Hound Dog

In 1957 the USAF issued specifications for a supersonic air-to-surface guided missile which could be carried far into enemy territory under the wing of a B-52 bomber and launched against strategic targets. The weapons system, which included the entire airborne and ground support equipment necessary for preparing the launch of the missile and for the firing itself, bore the designation WS.131B. The Missile and Information Systems Division of North American Aviation was appointed prime contractor for the missile, which received the designation GAM-77 *Hound Dog*.

The *Hound Dog* is reportedly able to carry a nuclear warhead with an explosive force of "several" megatons. It is fitted with an inertial guidance system developed by the Autonetics Division of North American. A star tracker is installed in the streamlined fairing of the suspension pylon under the wing of the carrier aircraft, to monitor the guidance system until the missile is launched. The position of the bomber is fed into the guidance system before the *Hound Dog* is released.

If the *Hound Dog* engine is used to boost take-off of the carrier aircraft, the missile's fuel tanks can be refilled by the bomber during flight.

The first fully inertial guided flight of a *Hound Dog* was made in October, 1959, and the missile went into service with Strategic Air Command in December, 1959. The first launch of a production missile was made by SAC crews on March 1st, 1960.

Powerplant: 1 Pratt & Whitney J52 turbojet with variable propulsive nozzle to adjust the thrust and turbine temperature in relation to flight conditions. Static thrust 8,000 lb.

Length 43 ft; Span 12 ft; Weight approx. 11,000 lb; Max. flight Mach number 1.6 to 2.1 depending on height; Design range approx. 600 miles; Range of Boeing B-52H carrier aircraft approx. 10,000 miles.

and temperature extremes during the 24-hour flight and then impacted upon its preselected target several hundred miles from the launch point.

The provision of operational *Hound Dog* missiles to several SAC wings only three years after production go-ahead attests to the calibre of the prime contractor's engineering staff, management and production personnel. And it also underscores *Hound Dog* versatility, ruggedness, reliability and accuracy—a fact of which potential aggressors are undoubtedly aware.

Production of the GAM-77 in one of North American's large assembly halls at Downey. Here several hundred *Hound Dogs* are in production for the USAF Strategic Air Command.

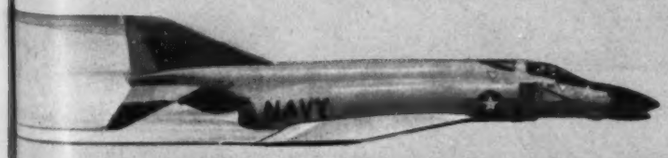
A PHANTOM

The twin air-induction systems of the Phantom II are unique. Their variable throats are so responsive to engine requirements they seem almost alive.

The thrust potential of the two J79-GE-8 engines is fully realized through the operation of the air-induction systems. This thrust powers the Phantom II to greater combat performance than any other service aircraft.

The air-induction systems are a triumph of internal and external aerodynamics. They are complex in concept, simple in execution, reliable in operations and remarkably efficient in all flight regimes. Each inlet system is comprised of a fixed ramp, an infinitely movable ramp creating a variable throat area and an engine by-pass. The movements of the ramp are programmed as a function of the engines' air flow requirements, the mach number and inlet air temperature—utilizing air-flow sensing devices, electrical controls and hydraulic/mechanical actuation. There is no excess flow to create drag, no insufficient flow to compromise power.

Altitude, speed and weapon-carrying capabilities have been combined in the Phantom II to a degree never before achieved in a combat aircraft. Now in production, the Phantom II offers flexible operational and armament capabilities for either police action or total war deterrence. The most versatile combat aircraft in existence, the Phantom II insures maximum defense for every defense dollar.



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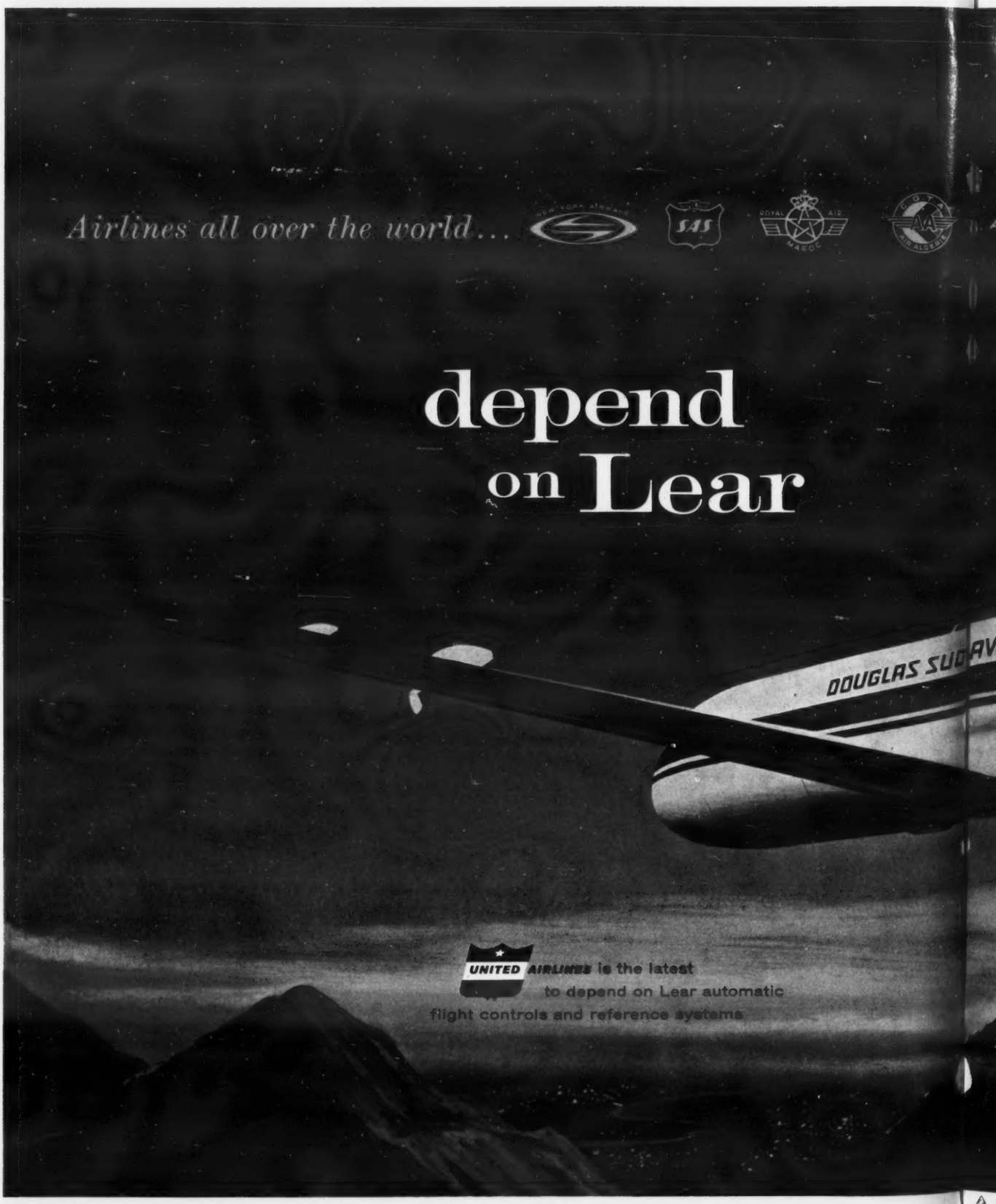

Lear L-102B automatic flight controls and dual CIS 100 command instrument system can be seen on the General Electric powered Caravelle.

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Missiles from A to Z

Only a few years ago it was a simple matter to keep a mental record of the names, manufacturers and applications of guided missile types, and even of a few technical data. Recently, however, their numbers have been increasing at an alarming rate, and even those for whom missiles are a day-to-day concern are no longer able to make do without references. The editors have compiled the following table to give readers a general survey of the situation. Designed for quick reference, the table makes no claims to completeness, but is restricted to some 130 types from eleven countries.

Designation	Manufacturer	Country [1]	Category [2]	Stage of development [3]	Max. range and remarks [4]
Alfa	Avco	USA	Surface-to-surface	O	ASW; N
Arm		USA	Air-to-surface	R	Anti-radar (USAF)
Asroc	Minneapolis-Honeywell	USA	Surface-to-surface	P	Several thousand yards; ASW; N
Astor	Westinghouse	USA	Surface-to-surface	D	20,000 yd; ASW; operational in 1961; N
Atlas SM-65A	Convair	USA	Surface-to-surface	O	9,000 miles; operational since September 1959; N; Atlas E under test since October 1960
Bantam	Bofors	SWE	Surface-to-surface	P	6,500 ft; anti-tank
Bat	BAC (English Electric)	GBR	Air-to-surface	R	N
Bloodhound Mk.1	BAC (Bristol/ Ferranti)	GBR	Surface-to-air	O	Anti-aircraft ; operational since mid-1958; Mk.2 under development, also an anti-missile version
Blue Steel	HSG (Avro)	GBR	Air-to-surface	D	200 miles; N; development of an improved version planned
Blue Water	BAC (English Electric)	GBR	Surface-to-surface	D	100 miles; N
Bomarc-A IM-99A	Boeing	USA	Surface-to-air	O	Over 200 miles; anti-aircraft; N; developed version IM-99B in production, operational in 1961; N
Bullpup ASM-N-7A/GAM-83A	Martin	USA	Air-to-surface	O	2 miles; operational since April 1959; GAM-83B version under development; N
Caisseur SE.4200	Sud-Aviation	FRN	Surface-to-surface	O	62 miles
Claymore		USA	Surface-to-surface	R	Short-range (U.S. Army)
Cobra Bö 810	Bölkow	BRD	Surface-to-surface	O	1,990 yd; anti-tank
Cobra		USA	Surface-to-surface	R	Anti-radar (U.S. Navy)
Corporal SSM-A-17	Firestone	USA	Surface-to-surface	O	75 miles; operational since 1955; N
Corvus ASM-N-8	Temco	USA	Air-to-surface	D	Over 100 miles; anti-radar
Crow		USA	Air-to-air	D	(U.S. Navy)
Davy Crockett	U.S. Army Rock Island Arsenal	USA	Surface-to-surface	D	5 miles; operational in 1961; N
Eagle AAM-N-10	Bendix	USA	Air-to-air	D	100 miles; N
Entac	DEFA	FRN	Surface-to-surface	P	1,900 yd; anti-tank
Fabmids		USA	Surface-to-air	R	U.S. Army mobile anti-missile system; research contracts received by Convair, Hughes, Martin, General Electric, Raytheon, Sylvania
Falcon GAR-1-D	Hughes	USA	Air-to-air	O	5 miles; further versions are GAR-2A, GAR-3 Super Falcon; GAR-4A; GAR-9 and GAR-11 (with nuclear warhead)
Field Missile	Chance Vought	USA	Surface-to-surface	R	

Designation	Manufacturer	Country [1]	Category [2]	Stage of development [3]	Max. range and remarks [4]
Firestreak	HSG (de Havilland)	GBR	Air-to-air	O	
Genie MB-1	Douglas	USA	Air-to-air	O	Unguided rocket; N
Gimlet		USA	Air-to-surface	D	Unguided rocket (U.S. Navy)
Hawk XM-3E1	Raytheon	USA	Surface-to-air	O	22 miles; anti-aircraft; Super Hawk under development
Honest John M-31	Douglas/ Emerson Electric	USA	Surface-to-surface	O	12 miles; N; XM-50 version under development
Hound Dog GAM-77A	North American	USA	Air-to-surface	O	500 miles; operational since December 1959; launched from Boeing B-52G carrier aircraft; N
Jupiter SM-78	Chrysler	USA	Surface-to-surface	O	Over 1,500 miles; N
Lacrosse SSM-A-12	Martin	USA	Surface-to-surface	O	20 miles; N
Law		USA	Surface-to-surface	D	Anti-tank (U.S. Army)
Little John XM-47	Emerson Electric	USA	Surface-to-surface	P	6 miles; operational in 1961; N
Lobber	Convair	USA	Surface-to-surface	D	6 miles; supply missile; development suspended
Longbow	Radioplane	USA	Air-to-surface	D	Anti-radar; successor to GAM-67 Crossbow
Lulu	General Mills/ Naval Ordnance Laboratory	USA	Air-to-surface Surface-to-surface	O	ASW; can be dropped from aircraft or launched by Asroc; N
Mace TM-76A	Martin	USA	Surface-to-surface	O	Over 650 miles; successor to TM-61 Matador; developed version TM-76B in production
Malaface	Latécoère	FRN	Surface-to-surface	P	30 miles
Malafon	Latécoère	FRN	Surface-to-surface	P	9 miles; ASW
Malkara	Government Aircraft Factories	AUS	Surface-to-surface	O	2 miles; anti-tank
Maruca	Fonderie de la Marine, Ruelle	FRN	Surface-to-air	D	Experimental weapon for Masurca and for training
Masalca	Latécoère	FRN	Surface-to-air	D	60 miles; anti-aircraft
Masurca	Fonderie de la Marine, Ruelle	FRN	Surface-to-air	D	19 miles
Mat TAT-M1	Kawasaki	JAP	Surface-to-surface	D	Anti-tank; operational in mid-1962
Matador TM-61	Martin	USA	Surface-to-surface	O	500 miles; production phased out; N
Mauler	Convair	USA	Surface-to-air	D	Anti-aircraft and anti-missile
Maw		USA	Surface-to-surface	D	Anti-tank (U.S. Army)
Midgetman		USA	Surface-to-surface	R	N (USAF)
Mightyman		USA	Surface-to-surface	R	N (USAF)
Minuteman SM-80	Boeing	USA	Surface-to-surface	D	6,350 miles; operational 1962/63; N
Missile A	ARGMA	USA	Surface-to-surface	D	15 miles; N
Missile B		USA	Surface-to-surface	D	N (U.S. Army)

[1] AUS = Australia; BRD = Federal German Republic; FRN = France; GBR = Great Britain; ITL = Italy; JAP = Japan; NOR = Norway; SOV = Soviet Union; SWE = Sweden; SWI = Switzerland; USA = United States of America. [2] The term "surface" also applies to anti-submarine missiles and those launched from submarines. [3] R = research or experimental; D = development; P = production; O = operational. [4] N = nuclear warhead.

Designation	Manufacturer	Country	Category	Stage of development	Max. range and remarks
Missile C		USA	Surface-to-surface	D	N (U.S. Army)
Missile D		USA	Surface-to-surface	D	N (U.S. Army)
Mosquito	Contraves-Oerlikon	SWI	Surface-to-surface	P	2,000 yd; anti-tank
Muroc		USA	Surface-to-surface	R	ICBM; N (USAF)
Nike-Ajax SAM-A-7	Western Electric	USA	Surface-to-air	O	25 miles; anti-aircraft
Nike-Hercules SAM-A-25	Western Electric	USA	Surface-to-air	O	100 miles; anti-aircraft; in service since July 1958; replaces Nike-Ajax; N
Nike-Zeus	Western Electric	USA	Surface-to-air	D	Anti-IRBM and -ICBM; N
Parca	DEFA	FRN	Surface-to-air	O	15 miles; anti-aircraft
Pershing	Martin	USA	Surface-to-surface	P	Over 300 miles; operational end-1961; N; further development Pershing 2
Petrel	Fairchild	USA	Air-to-surface	O	Shipping strikes; production phased out
Polaris A-1	Lockheed	USA	Surface-to-surface	O	1,500 n.m.; operational since November 1960; developments are A-2 with 1,800 n.m. range and A-3 with 2,500 n.m. range; N
Python	Pye	GBR	Surface-to-surface	D	Short-range; for launching from the ground or from light vehicles
Quail GAM-72A	McDonnell	USA		O	230 miles; decoy launched from Boeing B-52 carrier aircraft
Rat	Naval Ordnance Test Station	USA	Surface-to-surface	O	5 miles; ASW; production phased out
Redeye	Convair	USA	Surface-to-air	D	Operations against low-flying aircraft
Redstone SSM-A-14	Chrysler	USA	Surface-to-surface	O	200 miles; operational since 1956; N
Red Top	HSG (de Havilland)	GBR	Air-to-air	D	14,000 yd; N
Regulus 1 SSM-N-8	ChanceVought	USA	Surface-to-surface	O	575 miles; operational since 1955; the Regulus 1 and 2 are now used only as target drones
Seacat	Short	GBR	Surface-to-air	D	Anti-aircraft
Seaslug	HSG (Armstrong Whitworth)	GBR	Surface-to-air	P	Anti-aircraft; operational in 1961
Semper *		USA	Air-to-surface	R	(U.S. Marines)
Sergeant	Sperry	USA	Surface-to-surface	P	85 miles; operational in 1961; N
Shillelagh	Aeronutronics	USA	Surface-to-surface	D	Short-range; N
Sidewinder AAM-N-7/ GAR-8	Naval Ordnance Test Station	USA	Air-to-air	O	11,000 ft; Sidewinder 1-C all-weather version under development
Skybolt GAM-87A	Douglas	USA	Air-to-surface	D	1,120 miles; operational 1964/65; for launching from Boeing B-52H and Avro Vulcan; N
Slam	Chance Vought	USA	Surface-to-surface	D	Nuclear ramjet powerplant
Snark SM-62A	Northrop	USA	Surface-to-surface	O	6,300 miles; operational since mid-1959; N
Sparrow III AAM-N-6	Raytheon	USA	Surface-to-air	D	Anti-aircraft
Subroc	Goodyear	USA	Surface-to-surface	P	25 miles; ASW; operational in 1961; N
Talos SAM-N-6	Bendix	USA	Surface-to-air	O	65 miles; anti-aircraft; can also be deployed against surface targets; N; Super Talos under development
Tartar	Convair	USA	Surface-to-air	P	Over 10 miles; operational in October 1961
Terne	Kongsberg Våpenfabbrikk	NOR	Surface-to-surface	P	2,500 yd
Terrier SAM-N-7	Convair	USA	Surface-to-air	O	12 miles; anti-aircraft; operational since 1956; Advanced Terrier in production
Thor SM-75A	Douglas	USA	Surface-to-surface	O	1,725 miles; N
Thunderbird Mk.1	BAC (English Electric)	GBR	Surface-to-air	O	Anti-aircraft; N; Thunderbird Mk.2 under development

Designation	Manufacturer	Country	Category	Stage of development	Max. range and remarks
Tigercat	Short	GBR	Surface-to-air	D	Anti-aircraft
Titan SM-68	Martin	USA	Surface-to-surface	P	6,300 miles; operational in mid-1961; N
Titan 2 SM-68B	Martin		USA Surface-to-surface	E	14,000 miles; storable propellants (nitrogen tetroxide and dimethylhydrazine); operational in 1963; N
Typhon	Westinghouse	USA	Surface-to-air	D	Anti-aircraft and anti-missile
Vigilant	BAC (Vickers)	GBR	Surface-to-surface	D	1,600 yd; anti-tank
Wagtail	Minneapolis-Honeywell	USA	Air-to-surface	D	For use by low-flying aircraft; can also be deployed against aerial targets
Willow	Chrysler	USA	?	D	U.S. Army
Zuni	Naval Ordnance Test Station	USA	Air-to-air	O	5 miles; unguided rocket
AA.20	Nord-Aviation	FRN	Air-to-air	O	2.5 miles
AA.25	Nord-Aviation	FRN	Air-to-air	O	Developed version of AA.20; 3 miles
AAM-2	Fuji	JAP	Air-to-air	D	Operational in 1963
AS.20	Nord-Aviation	FRN	Air-to-surface	O	2.5 miles
AS.25	Nord-Aviation	FRN	Air-to-surface	O	3 miles
AS.30	Nord-Aviation	FRN	Air-to-surface	D	7 miles; N
C.7	SISPRE	ITL	Air-to-air	D	Operational in 1961
HM-55	Hughes	USA	Air-to-air	D	Can also be deployed against ground targets
HM-58	Hughes	USA	Air-to-air	D	Can also be deployed against ground targets; N
HM-61	Hughes	USA	Surface-to-air	D	
M-2		SOV	Surface-to-air	O	20 miles; anti-aircraft
M-55		SOV	Surface-to-surface	P	Tactical missions
M-55	Norris Thermador	USA	Surface-to-surface	O	Poison gas rocket
PT.428	BAC (English Electric)	GBR	Surface-to-air	R	For deployment against low-flying aircraft
PV	Pye	GBR	Surface-to-surface	D	Anti-tank
R.422B	Matra	FRN	Surface-to-air	D	30 miles; anti-aircraft
R.511	Matra	FRN	Air-to-air	O	4.5 miles
R.530	Matra	FRN	Air-to-air	D	Operational in early 1962
RSD.58	Contraves-Oerlikon	SWI	Surface-to-air	P	19 miles; anti-aircraft; training version RSC.57
SE.4400	Sud Aviation	FRN	Surface-to-air	D	30 miles; anti-aircraft
SS.10	Nord-Aviation	FRN	Surface-to-surface	O	1 mile; anti-tank; can also be launched from aircraft
SS.11	Nord-Aviation	FRN	Surface-to-surface	O	2.2 miles; anti-tank; can also be launched from aircraft
SS.12	Nord-Aviation	FRN	Surface-to-surface	D	4 miles; anti-tank; can also be launched from aircraft; to go into production in mid-1961
T-1		SOV	Surface-to-surface	O	450 miles; also known as M-101
T-2		SOV	Surface-to-surface	O	1,800 miles; N
T-3		SOV	Surface-to-surface	O	Over 8,000 miles; N; also known as M-104
T-5		SOV	Surface-to-surface	O	10 to 15 miles
T-7		SOV	Surface-to-surface	O	50 miles
TAAM-1D	Fuji	JAP	Air-to-air	D	8,200 ft; experimental version of AAM-2
TBM		USA	Surface-to-surface	R	For tactical missions (USAF; U.S. Army)
TBX		USA	Surface-to-surface	R	For tactical missions (USAF)
TMB-0	Mitsubishi	JAP	Surface-to-air	D	Anti-aircraft
TSAM-1	Mitsubishi	JAP	Surface-to-air	D	Anti-aircraft
XM-72	Hesse-Eastern Div., Flightex Fabrics	USA	Surface-to-surface	D	Anti-tank; to go into production in 1962
304	Robotbyrån	SWE	Air-to-surface	O	2.8 miles; operational since early 1959
315	Robotbyrån	SWE	Surface-to-surface	O	11.5 miles

Dyna-Soar

A Problem with Countless Unknowns

Ignored by the general public, official reports from the USA have recently mentioned a number of projects for manned space-bombers capable of circling the earth on any desired low- or high-altitude orbit and directing their nuclear charges at any point on the earth's surface.

These projects have again focused attention on the *Dyna-Soar* space glider, which has been under development for three years, but which has of late been somewhat neglected by politicians and military thinkers in favour of unpowered space vehicles like *Discoverer* and *Mercury*. Although it was tempting to proceed along the path which promised the most rapid arrival at the manned space vehicle, responsible planners have realized that the first man in space can offer his nation little more than a gain in prestige. Although projects such as *Mercury* can provide valuable information on the suitability of man as an astronaut, he can prove his abilities as a thinking being only in a space vehicle which he can direct according to his will. While in interplanetary or interstellar space he can only employ reaction energy to correct any deviation from ballistic trajectory, in a space vehicle operating near the earth he can make use of aerodynamic control.

For the future projects mentioned above, the Air Force is giving consideration to the possibility of using the atmosphere as a working medium; the *Dyna-Soar* project will certainly make use of aerodynamic forces to control the vehicle. Even with this "simple" space glider scientists are already facing a host of problems such as are rarely encountered in any development programme.

In the case of ballistic re-entry the friction heat generated, although severe, is of short duration; on the flat re-entry paths of aerodynamic vehicles, however, intense heat is generated over a longer period, heat which neither heat sink procedures or ablating covers can fully counteract. In such cases most of the heat must be radiated back into its surroundings. As, however, the heat radiated by a body is proportional to the fourth power of its temperature, the thermal equilibrium can be achieved only at very high temperatures—temperatures at which any conventional material loses its rigidity or even vaporizes. But it is not only fierce heat that the surface of the vehicle must withstand; there are also the erosive effects of flow and micrometeorites, together with cosmic radiation and the secondary radiation which it generates. Finally, account must be taken of the fact that the properties of materials often alter considerably in a high vacuum. All these factors have obliged designers to resort to "exotic" materials, for which methods of working, forming, riveting, welding and testing must first be found. There is an enormous variety of alloys, based on columbium, molybdenum, tantalum and tungsten, but even these tend to oxidize at very high temperatures and therefore require a penetration-free surface protective layer.

Despite the existence of these relatively temperature-resistant materials, it is essential to provide the parts of the skin which are the most exposed to heat—fuselage nose, wing leading edges and control surfaces—with additional protection in the form of an ablative layer, which will naturally be renewed after every flight and will therefore involve a considerable increase in operating costs. Finally, the construction must make adequate allowance for the stresses and strains arising as a result of the extremes of temperature encountered.

It is particularly unfortunate that the mechanical and thermal stresses experienced during re-entry are very difficult to evaluate in advance. The Wright Air Development Division has spent $7.7 million on a test rig which will enable hydraulically regulated forces to be applied to thousands of points on the airframes of *Dyna-Soar* prototypes, while infra-red radiators generate surface temperatures of 3,000° F. Such tests, however, require a knowledge of the forces and temperatures likely to be encountered during re-entry. Apart from a few simple instances, there are so far no precise mathematical formulae defining hypersonic flow processes. And wind-tunnel tests in this speed range can at present be carried out only for fractions of a second.

As recently announced by Captain Frank R. Anderton, who is working on the *Dyna-Soar* development programme at the USAF Flight Test Center at Edwards Air Force Base, all wind-tunnel tests—at speeds ranging from subsonic to supersonic—will in future be carried out at five different facilities, to eliminate as far as possible errors inherent in the facilities themselves.

Although it is easier to calculate than pressure distribution, temperature distribution also constitutes a severe problem to research scientists. In a single orbit around the earth, the *Dyna-Soar* would be enveloped in gases which are either ionized or in a state of dissociation. And if the degree of ionization rises by as much as one per thousand, there is a considerable change in the temperature arising from aerodynamic heating.

To obtain reliable data on mechanical and thermal stresses, the Air Force is to carry out free-flight tests with models this year. The Flight Sciences Laboratory is building two aerodynamic models, which are to be sent into the upper atmosphere from Cape Canaveral by *Blue Scout* booster. While, however, the laws of aerodynamics enable geometrically similar flow processes to be achieved with reduced-scale models, hence making possible the determination of air loads, knowledge regarding internal forces and the deformations which they cause can be gained only from full-size vehicles. McDonnell Aircraft Corporation is at present developing so-called structures models of the *Dyna-Soar*; each of these will contain a full-size part of the structure, which will be fitted in the model in such a way that it can be subjected to the same stresses as a complete space vehicle during flight tests.

Although these model tests can be of assistance in investigating basic flight characteristics and determining the order of the forces exerted on the aircraft, only a comprehensive programme of flight tests with complete space gliders can provide the necessary information on stability, controllability and the reliability of the individual vehicle systems.

Provided development proceeds according to plan, the Air Force intends in 1962 to tow manned *Dyna-Soar* prototypes to the stratosphere by B-52 bombers and there release them. The first flights will be made at subsonic speeds and will serve to test the stability and controllability of the *Dyna-Soar* during approach to land, and to familiarize pilots with this completely new aircraft category. *Dyna-Soar* pilots will first undergo a thorough training on simulators and the Lockheed F-104; a modified version of the latter has been found to have similar characteristics in gliding flight and a similar trajectory to the *Dyna-Soar*. Later, the *Dyna-Soar* is to be fitted with small rockets to accelerate it to supersonic speed after release. Here it is hoped to make use of experience gained with the X-15.

For 1963, the programme envisages the first launchings of *Dyna-Soar* mockups with modified *Titan Is* as boosters; Martin Company technicians hope that these modifications will be of a relatively minor nature. Undoubtedly, the transport of a body which is not symmetrical with respect to its axis will require additional stabilization surfaces on the booster, as well as certain reinforcements to the airframe. Finally, special monitoring and warning systems will be necessary to ensure the safety of the pilot, together with a cabin ejection device which can be released in a fraction of a second. Following these first unmanned tests, during which the *Dyna-Soar* will be remotely guided into its re-entry trajectory after release from the booster, the programme will enter its third and last phase, namely space flights with a manned vehicle. The first flights will doubtless be made over relatively short distances, with islands in the Atlantic Ocean being used as landing grounds. This will reveal the extent to which man, as an " autonomous component of the control system," will be capable of guiding a space vehicle. Before then, however, the *Mercury* programme will have yielded information on environmental influences such as weightlessness, radiation, heat, noise, vibrations and psychological effects. The Boeing Space Medicine Section is already simulating these conditions as far as possible and is studying the physiological reactions of man in a specially designed test chamber. The climax of the tests will be reached when the *Dyna-Soar*, accelerated to orbital velocity by a *Titan I*, will circle the earth, re-enter its atmosphere on a flat gliding trajectory and land at Edwards Air Force Base.

*

There can be no doubt that the concept of the manned, controllable space glider offers more possibilities for development than a ballistic re-entry capsule. Quite apart from its strategic applications, a controllable vehicle which can remain above the earth for long periods has all the prerequisites for comprehensive upper atmosphere research, which is not the case with ballistic vehicles. Even today, NASA is planning to use the *Dyna-Soar* for geomagnetic measurements, solar observation and similar applications. Even if one day "all-out peace" should be declared, the expense of developing the *Dyna-Soar* will be more than justified.

Flight Propulsion

Left to right : Lt. Col. T. H. Miller, USMC ; Vice Admiral W. F. Raborn, Jr., USN ; J. D. Wethe, General Electric ; Cmdr. J. F. Davis, USN ; D. D. Clark, McDonnell Aircraft.

G. E. trophy goes to F4H pilots

NEW ORLEANS, La.—The General Electric trophy for significant achievement in military aviation in 1960 has been presented to the U.S. Navy and the two pilots who set new world speed records with the Navy's McDonnell F4H Phantom II fighter.

Joint recipients of the award are Lt. Col. T. H. Miller, USMC, who set a new 500 km record of 1216 mph; and Cmdr. J. F. Davis, USN, who set the 1390-mph 100-km run record.

The trophy was presented Jan. 13 at a regional Navy League meeting. In making the award, J. D. Wethe, an executive of G.E.'s Large Jet Engine Department, cited " the outstanding capability of the Naval air arm and the pilots who fly the Navy's jets."

The F4H in which Lt. Col. Miller and Cmdr. Davis set the closed-course records was powered by twin G-E J79-2 test engines. The Phantom II is now flying with the J79-8, an improved production engine. The more powerful 8 produces over 16,000 lbs of thrust.

Its 12 : 1 compression ratio helps to make the F4H the Navy's fastest, highest-climbing, longest-ranged fighter. *For additional information on the F4H/J79, check GED-4106. See coupon.*

J85-POWERED GAM-72A MISSILE COMPLETES CATEGORY I TESTS

LYNN, Mass.—The GAM-72A " Green Quail," a decoy missile powered by General Electric's J85-7 turbojet engine, has completed Strategic Air Command Category I testing.

All flight tests with the G-E engine were successful. The 650-mph diversionary missile, designed and produced by McDonnell Aircraft Company, has been undergoing development and flight tests since 1959.

The GAM-72A " Green Quail " decoy missile has completed SAC Category I testing. At right is General Electric's J85-7 turbojet engine, which powers the 650-mph missile.

" Green Quail's " J85-7 turbojet powerplant develops 2,450 pounds thrust. Dropped in coveys by a B-52G mother ship, the missile is designed to confuse enemy air defenses by simulating the B-52 on enemy radar screens.

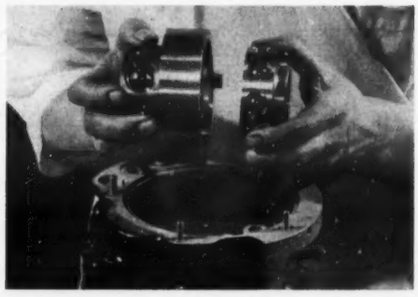
For more information on J85 turbojet engines, check GED-4095. See coupon.

F4H Features Unique Hydraulic Constant Speed Drive System

LYNN, Mass.—A unique G-E hydraulic constant speed drive powered the electrical system for the McDonnell F4H Phantom II during its record speed runs.

Two parallel 20-kva drives transform the variable speed of the twin J79 powerplants to the constant speed required by the aircraft's a-c generators. The drives, which can " lock " together to divide load, maintain system frequency constant within ± one-tenth of a percent.

The G-E drive is a compact radial-piston hydrostatic transmission that features free spherical pistons rather than conventional restrained cylindrical pistons, connecting rods, and associated bearings. The simple design concept has demonstrated reliability of .9997 per hour in over half a million operating hours in other aircraft applications.



Small ball piston elements, key transmission components of the hydraulic system.

The General Electric F4H electrical system contains several innovations for U.S. Navy " production " aircraft, including:

- First application of an integrated drive-generator package.
- First application of oil-cooled generators to provide environment-free conditions.
- First " high temperature " drive, operating continuously at 300F.

For more information about constant speed drives, check GEA-6890. See coupon.

NEWS

A report about progress in research and products from the Flight Propulsion Division of the General Electric Company

CONVAIR 990 LOGS FIRST FLIGHT

SAN DIEGO, Calif.—The first flight of a second generation jet airliner, Convair's 990 Coronado, was logged here on January 24 as the swift aft-fan transport climbed aloft on a 2-hour, 3-minute maiden flight.

Powered by four 16,100 thrust-class General Electric CJ-805-23 aft-fan engines, the 990 flew at speeds up to 500 mph and altitudes to 25,000 feet.

A medium/long range jet capable of operating from 5000-foot runways, the 990 is designed to carry 96-121 passengers. Cruising at 640 mph, it will be the world's fastest airliner, and is expected to cut transcontinental non-stop flight time by as much as forty-five minutes.

The aircraft is scheduled to enter commercial service in mid-1961. In addition to speed and short-runway advantages, 990/CJ-805-23 operators will benefit from improved specific fuel consumption and quieter engine operation.

For more information on the Convair 990/CJ-805-23 check GED-4284. See coupon.

A single General Electric CT58 powers the Sikorsky S-62, with 10 passengers aboard, at 100 mph. S-62 will soon be in service for San Francisco-Oakland Helicopter Airline.

Second California Airline to Offer Turbocopter Service

SAN FRANCISCO, Calif.—San Francisco-Oakland Helicopter Airline recently announced plans to inaugurate Sikorsky S-62 turbocopter passenger service in the Bay area April 1, 1961.

Both the new airline and the Los Angeles Airways will be offering CT58 turbine-powered passenger service. The S-62 has serviced communities in the Los Angeles area since December. The new turbocopter has demonstrated its speed by flying 10 passengers from the Los Angeles airport to Azusa in 15 minutes—a distance usually requiring a 1-hour-and-40-minute drive.

M. F. Bagan, president of the San Francisco-Oakland line, said, "The excellent power-weight ratio of the CT58 engine and the proven components of this aircraft make the S-62 the most dependable helicopter ever built." Community spokesmen also commented that "its turbine engine makes it a very quiet aircraft."

Producing 1050 horsepower and weighing only 280 lbs, the economical CT58 weighs only 33% as much as reciprocating engines of the same rating. Fifty-five inches long, it requires only 25% of the space of similarly rated conventional powerplants.

Los Angeles Airways, New York Airways, and Chicago Helicopter Airways will fly turbocopters with twin CT58 powerplants in 1961.

For more S-62/CT58 information, check GED-3987A and GED-4236. See coupon.

G-E lift fan completes 90 hours' operation

EVENDALE, O.—General Electric recently logged another important step in its lift fan flight test program, completing 90 hours of operation. Fifty hours of wind tunnel testing were included in the operation.

The lift fan will permit tactical military or commercial aircraft to take off or land vertically, yet cruise as present jets do. A lift fan-powered aircraft flight test is planned for 1963.

During the recent program, the G-E lift fan engine system, powered by the 2450 pound thrust-class J85-7 engine, was mounted in a wind tunnel aircraft mock-up.

General Electric engineers have discovered that the lift of the airplane/lift-fan combination is greater than the lift of either of them measured separately.

This additional "interaction" lift is attributed to the fan pulling air through from above, creating a force on top of the wing to give the vehicle this lift bonus. Interaction lift helps assure flight over varying flight conditions.

G-E lift fan is designed for horizontal mounting in the fuselage or wings of VTOL aircraft. It is shown here in vertical position, during plant inspection.

FOR MORE INFORMATION

General Electric Company
Section C 206-22
Schenectady 5, N.Y.

- ☐ GER-1704 "F4H AC Electrical System"
- ☐ GEA-6890 "Constant Speed Drives"
- ☐ GEA-7105 "Advances in Nuclear Aircraft Propulsion"
- ☐ GED-3987A & GED-4236 "CT58"
- ☐ GED-4106 "F4H /J79"
- ☐ GED-4284 "CJ-805 Progress Report"
- ☐ GED-4095 "J85"

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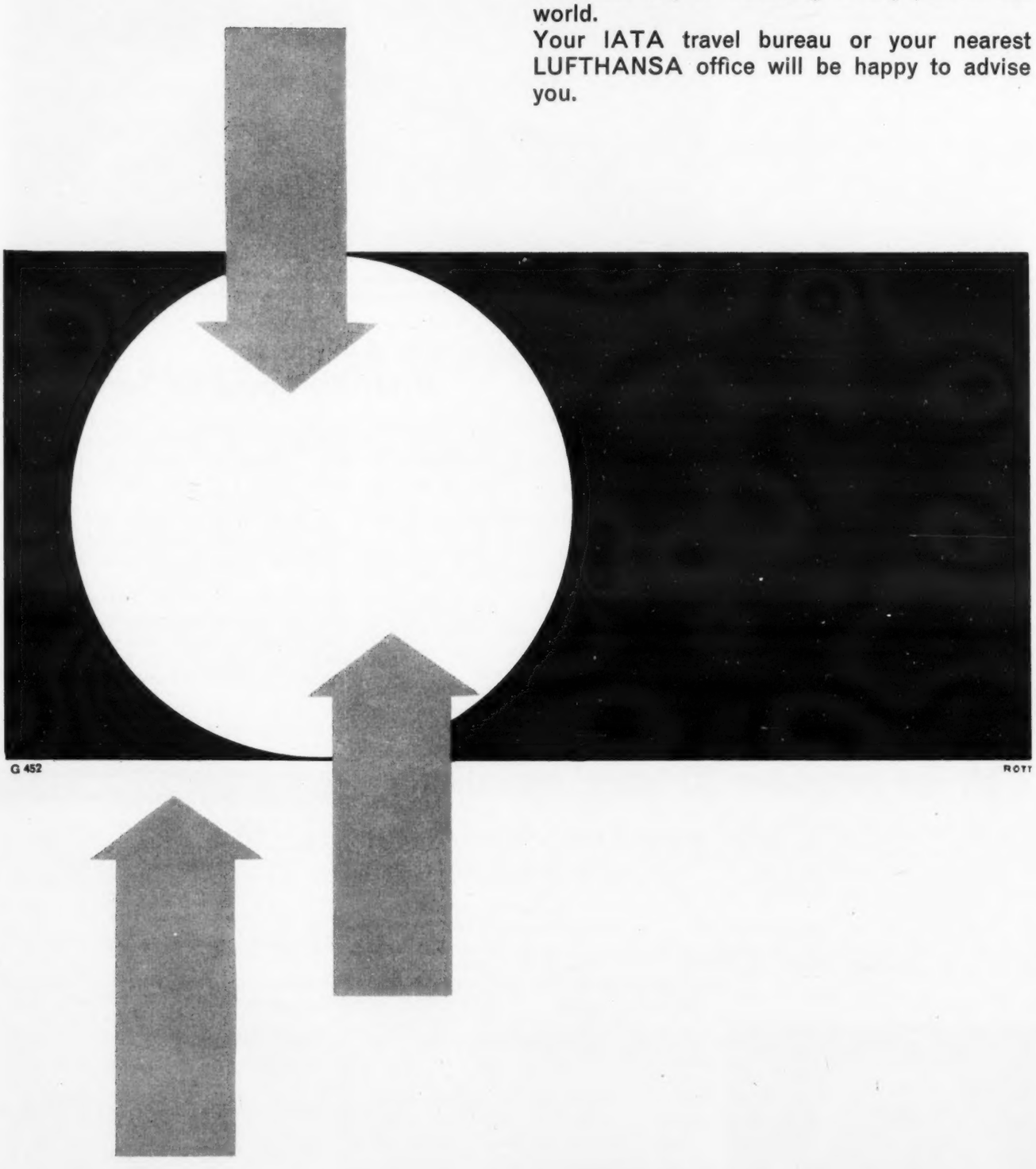

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GNOME

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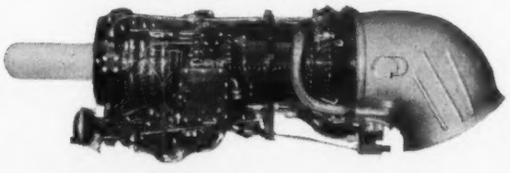
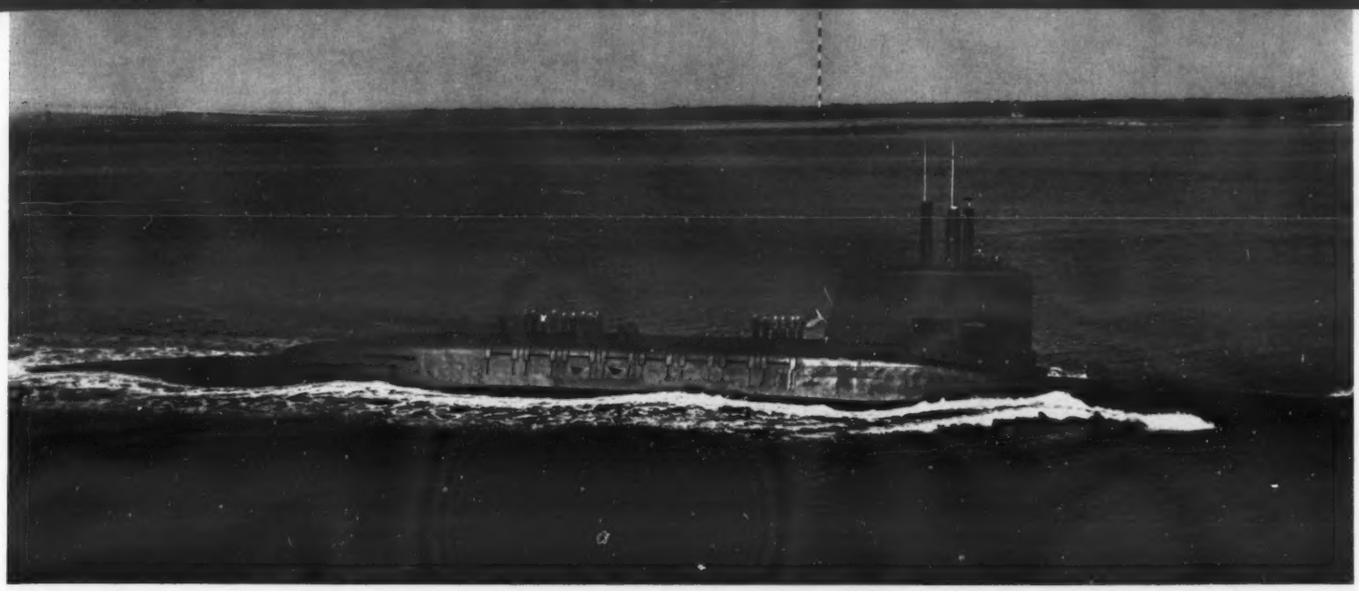


The Gnome 1000 s.h.p. free-turbine engine with an effective diameter of only 16 inches, weighs less than 300 lb.

THE DE HAVILLAND ENGINE COMPANY LIMITED, Leavesden, Hertfordshire

Member Company of the Hawker Siddeley Group



The third *Polaris* submarine, USS *Robert E. Lee*, leaving the naval base of Charleston, South Carolina.

Future of the Polaris ICBM

In the unanimous view of the strategists, the value of a deterrent force is measured by the degree of destruction which it can inflict on the enemy *immediately* a conflict starts. To be effective in retaliation, the weapon must be able to survive the enemy's first blow. Accordingly, ability to survive is the decisive factor in the choice between various deterrent weapons of equal striking power.

Both engineers and defence planners are convinced that the *Polaris* submarine rocket, built by order of the U.S. Navy, has considerable chances of survival and moreover that, owing to the unlimited range of the atomic powered carrier submarines, it is a valuable means of global retaliation. The successful launchings of two *Polaris* rockets from the submerged USS *George Washington* on July 20th, 1960, concluded for the time being the development programme for the *Polaris* weapon system, which had been pushed forward under the energetic leadership of Rear Admiral W. F. Raborn. Now the U.S.Navy need have no qualms about including several dozen atomic powered missile submarines in its building programme over the next few years. Although so far approval has been given for only 21 submarines, this should be sufficient for the time being to relieve anxiety about the vulnerability of the American potential for retaliation.

Three technical achievements were indispensable in realizing the construction of medium range ballistic rockets of the *Polaris* type, namely improvement of the solid propellants, reduction of the weight and space taken up by the guidance and control systems, and reduction in the size of the nuclear warhead. All this progress was the fruit of the *Polaris* rocket programme. Most important of all, however, was the U.S.Navy's success in making the *Polaris* operational three years in advance of the date originally envisaged.

Since November 15th, 1960, American atomic submarines, each armed with sixteen *Polaris* rockets, have been cruising the oceans, on the alert. As part of the plan to ensure the permanent operational readiness of each vessel and its missiles, two complete crews ("blue" and "gold") alternate in manning each submarine.

Even following an atomic attack directed against the North American Continent, these submarines could continue to operate at sea for weeks, lying ready to launch their missiles on the receipt of orders from Naval Headquarters or the Head of State. If the catastrophy was on such a scale to eliminate the possibility of receiving such

A Lockheed *Polaris* IRBM ready for launching from a special platform at Cape Canaveral missile range. The nose cone does not carry a nuclear warhead, but is fitted with a variety of measuring instruments.

orders, it would be possible for the Commander of a *Polaris* submarine to make his own decision, based on the picture of the general situation obtained by monitoring radio stations in various parts of the world. He would in any case have already been given the targets to be attacked.

Retaliation weapon for NATO?

Some time ago an American technical journal reported on studies undertaken as to how to increase still further the degree of mobility of the Polaris system already achieved by the U.S.Navy with its missile submarines. The fundamental problem, today largely solved, was to simplify the operation of the missile and to reduce the dimensions of both the control units and the launching gear to the point where the missile could be incorporated into a completely mobile weapons system and transported without difficulty by land vehicles and surface ships. By building on these foundations, NATO could also obtain the retaliation weapon, which has been demanded on many sides, quickly and without risking large expenditure on development, always provided that the proposals made by the United States to the Council of Ministers of the NATO Powers in 1960 are acceptable. This is a thought already touched upon in the leading article.

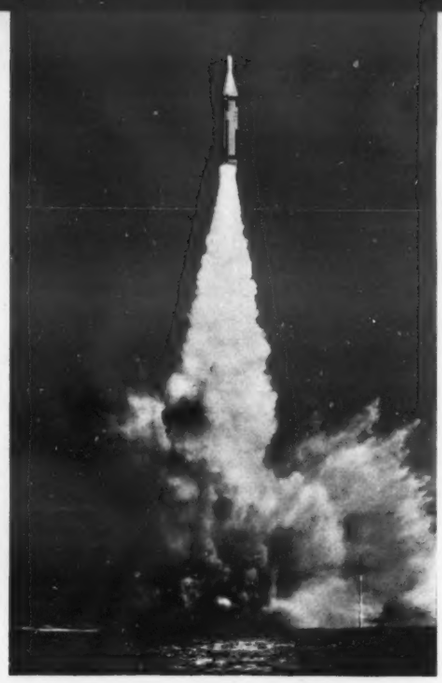
Briefly, at the Paris negotiations, the Americans expressed their readiness to put five missile submarines with a total of 80 *Polaris* missiles at the disposal of NATO by the end of 1963. These submarines would, in the U.S. proposal, be allocated to the U.S.Sixth Fleet, be under American command, and not be used to engage the targets selected except on the orders of the Commander, U.S. Sixth Fleet. They could, however, be manned by mixed European-American crews, and NATO would be given the possibility of participating in the control of these submarines and in the selection of targets which could, when necessary, be of a "semi-tactical" nature.

As former U.S. Secretary of State, Herter stated at the time, the United States expected that its NATO partners would, in exchange, provide resources for the construction of a further 100 medium rockets, preferably for use at sea.

The Paris offer was preceded by a secret session of the Joint Chiefs of Staff in November 1960, at which these problems were considered. Moreover a Pentagon spokesman stated that, should NATO refuse to build land or sea based *Polaris* missiles, this would probably not mean that the delivery of the solid propellant *Pershing* missile, proposed by the U.S. Army, would be forced on them as the alternative.

In the course of the Paris negotiations, the American delegates put forward various arguments in favour of the *Polaris* as a European retaliation weapon. Although these arguments did not meet with the approval of all delegates, they were strongly supported by Dr. Adenauer, the West German Chancellor, who advocated that instead of using submarines the hundred additional rockets should be carried on board normal merchantmen which would be under the full control of NATO, as it would take too long for NATO to build its own fleet of *Polaris* submarines. Time being a decisive factor, the only rational way for NATO to use *Polaris* missiles would be to install them on merchantmen. The advantage of the submarine is naturally that the enemy is in practice deprived of all possibilities of detection, although *Polaris* surface vessels could be camouflaged as ordinary freighters and thus also protected from enemy attack. Adenauer's last point was that the cost of building atomic-powered *Polaris* submarines – some $120 million – would be prohibitive for the European allies.

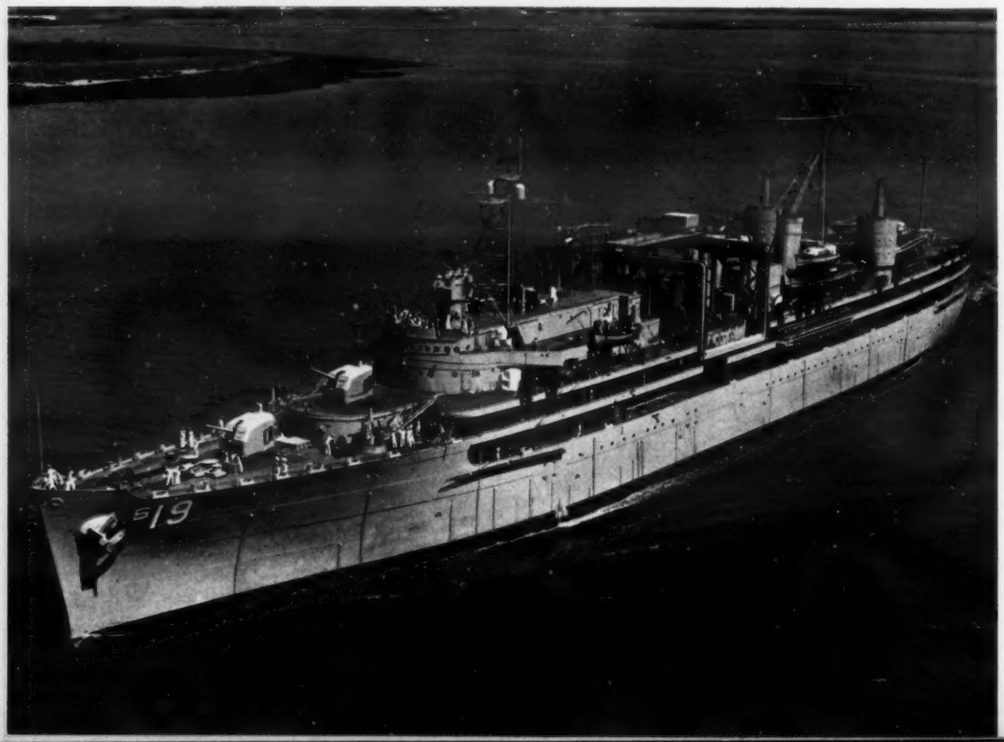
It is meanwhile no longer a secret that the opinions of NATO members are very divergent and that a decision on the NATO medium range rocket has been postponed until the NATO Ministers meet in Oslo in May.



This launching, the second of a production *Polaris A-1* from the submerged submarine *George Washington*, took place on July 20th, 1960 and marked a milestone in the American missile programme. It also marked the climax of the *Polaris* programme, which has been proceeding at full pressure for the past three years.

Federal German Defence Minister Franz Josef Strauss in conversation with Rear Admiral W.F.Raborn, Director of the U.S. Navy Special Projects Office and of the *Polaris* programme. In the background is Herschel J. Brown, General Manager, Lockheed Missiles and Space Division, who discussed the *Polaris* in detail with the German Defence Minister when he visited the Division at Sunnyvale.

The *Polaris* submarine depot ship USS *Proteus* (AS-19) supplies the U.S. Navy's missile-carrying submarines in overseas ports with *Polaris* weapons and general supplies for the nuclear-powered submarines which they arm. The *Proteus* is at present cruising off the Scottish coast and is reportedly based at a Scottish port.



Be that as it may, the arguments so far brought up in discussion are worth briefly summarizing under headings.

Relatively low cost

Since the main effort on development and testing has already been financed, smaller initial costs would be incurred than in the case of weapons systems which have to be built from scratch.

Quick availability

The *Polaris* is a solid propellant medium range ballistic missile, which already complies to a large extent with NATO requirements. Being already in service with the U.S.Navy, it could be operational before other medium range rockets which have been offered to NATO; 20-24 months after the decision on using the missile in Europe, the sea or land forces would get their first *Polaris* units.

Operational testing completed

The NATO forces would get the benefit of two years American operational experience as well as the intensive testing and development programme already undertaken.

Suitability

The missile is suitable for a large number of launching installations, both mobile and fixed. It can be carried by road vehicles and railway trains, as well as by ocean-going or river vessels.

Technical Data ...Concerning the Polaris Missile

Length of missile including nose cone . . . . . 28 ft
Diameter . . . . . 4 ft 6 in.
Burnout speed . . . . . approx. Mach 10
Range of A-1 version . . . . . 1,200 n.m.

The first and second stage engines (both by Aerojet-General) have four nozzles each, the thrust vectors of which can be swivelled for controlling the missile by means of jet deflection rings.
Thrust of first stage engine: approx. 55,000 lb.
Solid fuel: Polyurethane perchlorate with aluminium additive.

The inertial guidance system, developed by the Massachusetts Institute of Technology, is understood to direct the missile on the target area with such accuracy that the warhead's average deviation from target is not more than a few hundred yards.

The re-entry body, developed by Lockheed in conjunction with NASA scientists, carries a nuclear warhead with an explosive effect of about a megaton. During launching and flight through the earth's atmosphere, the nose cone remains covered by an extremely hard and highly insulated material, which does not ablate until re-entry into the denser air layers. The nuclear warhead is produced by the Livermore Laboratory of the Atomic Energy Commission in co-operation with Sandria Corp., Albuquerque, New Mexico.

Main contractor for the missile: Missiles and Space Division, Lockheed Aircraft Corp., Sunnyvale, Calif.

Main sub-contractors:
Propulsion system: Aerojet-General Corp., Sacramento, Calif.
Guidance system: Ordnance Department, General Electric Co., Pittsfield, Mass.; Hughes Aircraft Corp., Culver City, Calif.
Checkout and readiness equipment: Nortronics Division, Northrop Aviation, Downey, Calif.

...and the Carrier Submarines

"George Washington" Class
Overall length . . . . . 380 ft
Beam . . . . . 33 ft
Standard displacement . . . . . 5,600 tons
Displacement (submerged) . . . . . 6,700 tons
Under-water speed . . . . . 30 knots
Surface speed . . . . . over 15 knots

Other submarines in the "George Washington" Class are the USS "Patrick Henry," "Theodore Roosevelt," "Robert E. Lee," and "Abraham Lincoln."

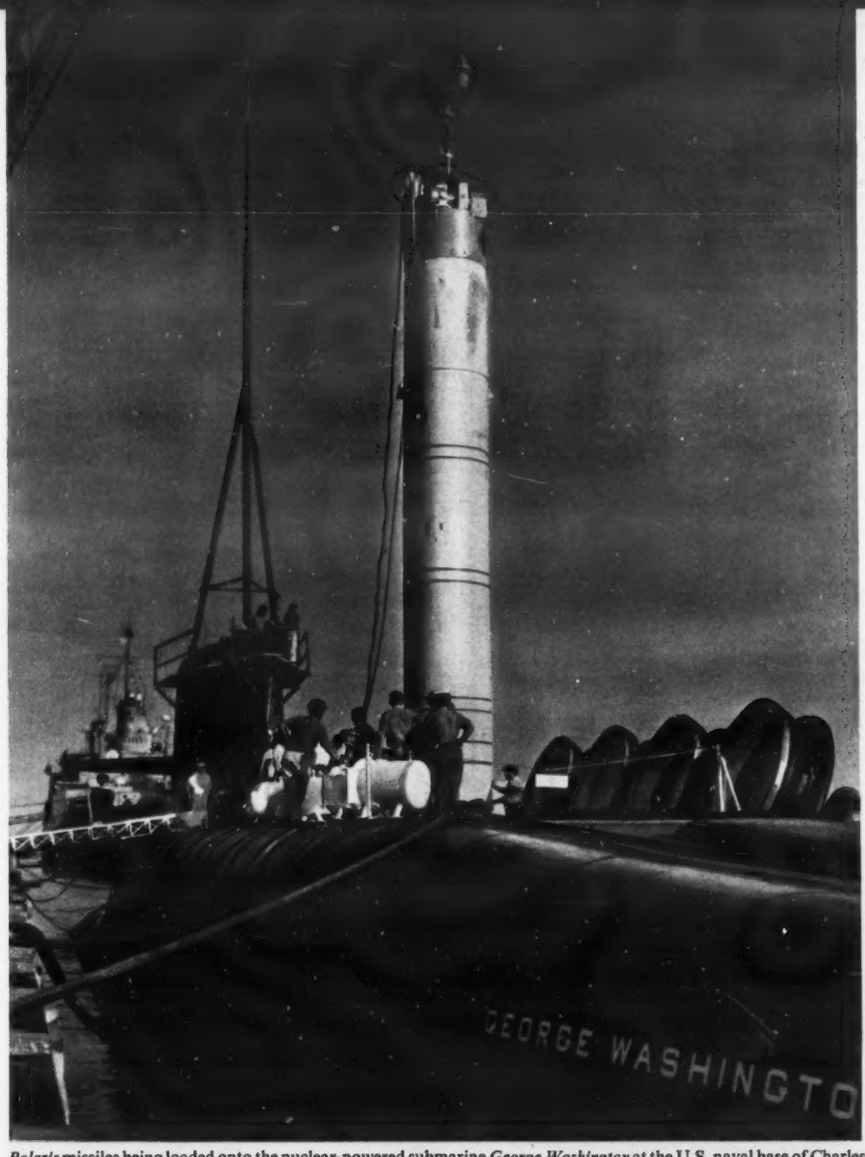
"Ethan Allen" Class
Overall Length . . . . . 410 ft
Beam . . . . . 34 ft
Displacement . . . . . 6,900 tons
Displacement (submerged) . . . . . over 8,000 tons
Speed . . . . . ?
Other submarines in the class are the USS "Sam Houston," "Thomas A. Edison," and "John Marshall."

Main contractors for the submarines:
Electric Boat Division, General Dynamics Corp., Groton, Conn.
Newport News Shipbuilding and Drydock Company, Newport News, Va.
Mare Island Naval Shipyard, Calif.
Portsmouth (N. H.) Naval Shipyard.

Atomic reactor for ship's engine:
Westinghouse Electric Corp., Pittsburgh, Pa.

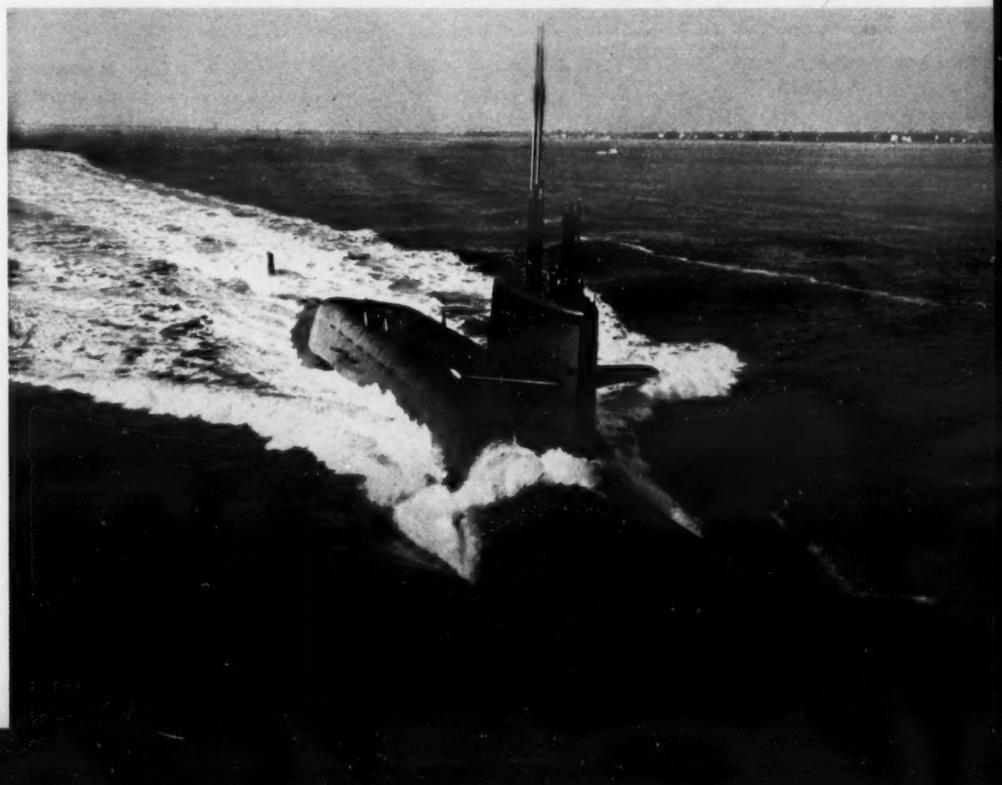
Ship's inertial navigation system (SINS) for underwater control:
Sperry Gyroscope Co., Great Neck, N.Y., and Autonetics Division, North American Aviation, Downey, Calif.

Launching and handling system:
Westinghouse Electric Corp., Sunnyvale, Calif.

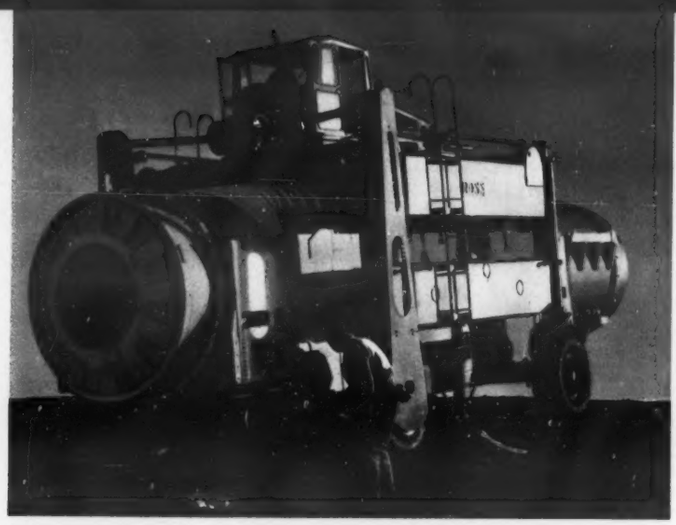


Polaris missiles being loaded onto the nuclear-powered submarine *George Washington* at the U.S. naval base of Charleston. The missiles are stowed in insulated shockproof containers with double walls and are let down into the submarine launching tubes by crane. To the right, the heavy lids which cover the last four starboard launching tubes.

A *Polaris* submarine steaming at full speed off the U.S. East Coast. Their clean hydrodynamic configuration enables the 400 ft submarines to reach underwater speeds of some 35 knots. The box-like structure behind the sail covers the launching tubes which project above the rounded hull of the vessel, and has a number of fins to smooth the water flow behind the sail. The fins at each side of the sail provide stabilization for the vessel during underwater cruise.

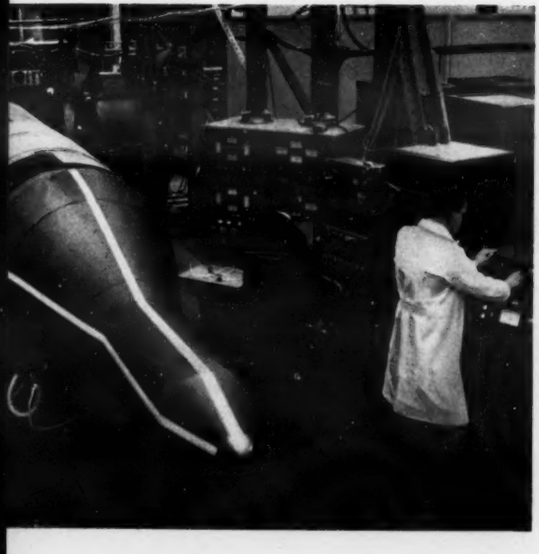


This four-wheeled monster is a special vehicle for the overland transport of complete *Polaris* transport container units. Inside the cylindrical housing are shock absorbers to support the container itself, and temperature and humidity controls.



Components of the electronic system being fitted in the conical transition section of the *Polaris* re-entry vehicle in the Lockheed Missiles and Space Division assembly hall.

Complete *Polaris* missiles can be subjected to systematic vibration tests in one of Lockheed's many laboratories at Sunnyvale.



"Underwater Missile Facility" is the given by Lockheed to this tank several feet deep, in which reduced-scale mockups of *Polaris* missiles are fired from model launching tubes in thousands of tests. Artificially generated waves in the tank and reduced air pressure in the experimental laboratory permit imitation of the environmental conditions encountered during actual firings. The technicians of this laboratory spend most of their time under water as frogmen. ▼

Further development potentialities

The basic concept of the *Polaris* allows of continuous further development. Recently, for example, it was announced that the present range of the weapon, namely 1,200 n.m., was to be increased to 2,500 n.m. without loss of existing mobility.

When discussing the suitability of any MRBM system for NATO purposes, there are two points to be specially borne in mind. First, the system should allow land and sea operation in combination, which seems indispensable in order to have the maximum benefit of wide geographical separation. Second, the marked variability of political, economic and climatic factors seems to favour a system whose components are to a considerable extent interchangeable and which allows maximum flexibility in deployment. In other words, the NATO Powers and the NATO commander must be put into a position where they can adapt the use of the weapon to suit prevailing military and political exigencies.

With its present range of 1,200 n.m. the *Polaris* can strike at practically all land and sea targets which the NATO forces may need. Work is, however, already in progress on increasing the range to 1,500 n.m. (Version A-2) and to 2,500 n.m. (Version A-3), the former to be ready in about a year and the latter before 1965.

The remarkably high accuracy already achieved by this missile further increases its suitability for NATO requirements. In the design of the *Polaris* and of its support equipment, account was taken of the fact that the missile would for longish periods have to be kept operational far from its maintenance bases, and would have to rely for months on the equipment carried aboard. From an economic point of view, a substantial part of the total cost of a weapons system of this type is accounted for by ground support and servicing installations. As shown by the studies so far produced, it would be possible to make use of many parts of the existing launching installations and testing systems in the seaborne version of the *Polaris* for NATO, and even future versions of the *Polaris* would be able to use the same support installations.

*

Should NATO meanwhile decide to adopt a mobile land version of the *Polaris* to the exclusion of other versions, the weapon together with its fire control system, signals equipment, and launching gear could, according to Lockheed, be mounted on one semi-trailer. These vehicles would then have 100,000 miles of road within NATO countries at their disposal, would be able to remain continuously on the move on first and second class roads, and could find widely separated points from which to operate. Systems for the maintenance, inspection, and overhaul of the weapons system will have to be set up at certain places. Whilst on the move, the missile unit would of course maintain permanent communication with its command and control base. The weapon could be ready to launch a few minutes after receipt of the order to do so.

*

Whatever NATO's decision may turn out to be, the U.S.Navy will give priority to this retaliation weapon for years ahead, and in this it can obviously count on the complete understanding of the American Defense Department. Out of the total of $3,900 million provided for the four major long-range weapon systems, namely *Atlas, Titan, Polaris* and *Minuteman,* in the fiscal year 1961, by far the largest share, amounting to $1,500 million, is allocated to the *Polaris* and to five new atomic-powered carrier submarines. These credits include some $400 million for research and development work on the A-2 and A-3 version of the *Polaris,* all of which leaves no doubt that the *Polaris* weapons system has a long life ahead of it. ←

The Small Deterrent

A, B, C, D, — these few provisional alphabetic designations represent about all that is so far known about the surface-to-surface missiles with atomic warheads, which are at present under development as the U.S. Army's standard tactical weapons of tomorrow. Behind these weapons is the endeavour of American strategists to take account of modern demands, a policy which is in many respects in contradiction to the conception of certain NATO powers.

Why, as time goes on, is there an increasing tendency towards building a complete arsenal of tactical atomic missiles? After all, a wide range—the Martin *Pershing* (range over 300 miles), the Sperry *Sergeant* and BAC *Blue Water* (for the medium range requirement), the Martin *Lacrosse* (20 miles) and the Emerson Electric *Little John* (6 miles)—is already represented, and this list still does not include the new one-man or two-man infantry weapons for front line use, say the *Davy Crockett* miniature rocket with a range of five miles.

Arguments in favour of building weapons of this type abound and only some of the major reasons will be touched on here, with no attempt to put them in order of importance.

Length of front, battle area and troop density

Quite apart from the uncertain value of the heaviest nuclear weapons as a sole deterrent, a question which is dealt with later on, the small land forces at the disposal of the West and the large areas they would have to hold should war occur, are themselves factors in favour of arming tactical surface-to-surface missiles with nuclear warheads.

The bitter controversies of two or three years ago as to what the strength of the so-called NATO protective shield for Central Europe should be are generally known. At that time, General Lauris Norstad, the Commander-in-Chief of NATO, and many other leading military experts took great pains to drive home to the European ministers of defence the fact that the Central European forces of the Western Allies would have to be raised from 21 to at least 30 divisions. Even an increase of a few divisions would not, however, fundamentally alter the frightening incongruity between the number of NATO formations and the areas for which they are responsible, the more so as the Soviet bloc could deploy a superiority of four or five to one.

The precarious situation of the West becomes clear if one thinks of the armies deployed in World War II. Today the NATO divisions in Central Europe would face a front stretching from the Alps to the Danish frontier, whereas at Stalingrad in 1942, for example, no less than 22 divisions (330,000 men) were engaged on the German side alone.

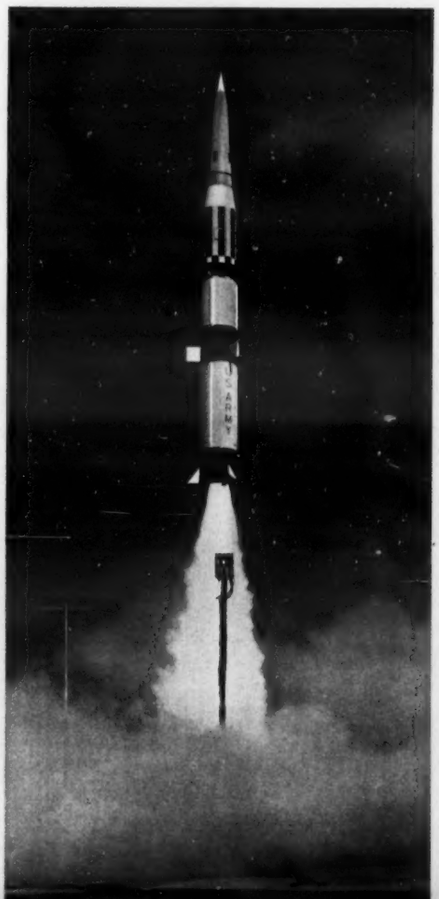
And the length of the total front is not the strategist's only headache. A further serious problem is the depth of the atomic battlefield and the relatively large areas which would be occupied by troops. In an atomic war of tomorrow, battle areas of a couple of hundred miles or so would have to be reckoned with, and inside these there would be great distances between the defender's individual corps and divisions which, becoming entirely self-dependent at the critical time, would have to operate as autonomous formations and carry all their own weapon requirements.

What they lacked in numbers could be then compensated for by their mobility and extensive armament.

Can one survive atomic war without atomic weapons?

The attitude of certain West European powers in recent years goes to show that they were not anxious to accommodate tactical American atomic forces on their territories or to have at their own disposal weapons which the East could consider as "provocation"—and which are, moreover, not exactly cheap!

A new version of the *Pershing* surface-to-surface missile being fired from a mobile erector/launcher. The missile is being developed by The Martin Company in collaboration with the U.S. Army.



Certain European general staffs seem, however, to have made a virtue of necessity. Since the politicians denied them atomic weapons, they produced the theory that, if necessary, successful resistance in an atomic war would be possible with conventional weapons too. According to such theories, wide separation, mobility and deep entrenchment must make it possible to escape mass destruction and continue the fight to a certain extent.

The New World has little understanding for such European theories. As far as heavy nuclear retaliation weapons are concerned, the Americans are convinced after their sad experiences in Korea and elsewhere that the deterrent effect is limited to global war and that such weapons are in no way able to avert lesser, although still comparatively serious, conflicts.

In the American appreciation, tactical atomic weapons admirably close the gap in the European situation for, by their very existence, such weapons make any use of force appear impracticable to the enemy, although their use constantly poses the danger that each side will force the other to increase his bid—in other words each side will have recourse to heavier, ultimately the heaviest weapons. And if the statements from behind the Iron Curtain are anything to go by, the Americans do not seem to be far wrong in their assumption.

Leading Russian soldiers and politicians have declared over and over again that the use of tactical weapons cannot be confined to tactical operations. The same thought, though in other words, was expressed by Mr. Khrushchev in his letter to the British Labour Party in October 1957: "It is to be recalled that both world wars started as limited military action, i.e., in their beginning both were local wars. In our time of rapid development of military technology it will be an even more difficult task to put any limits on an armed conflict if this conflict starts in any single region."

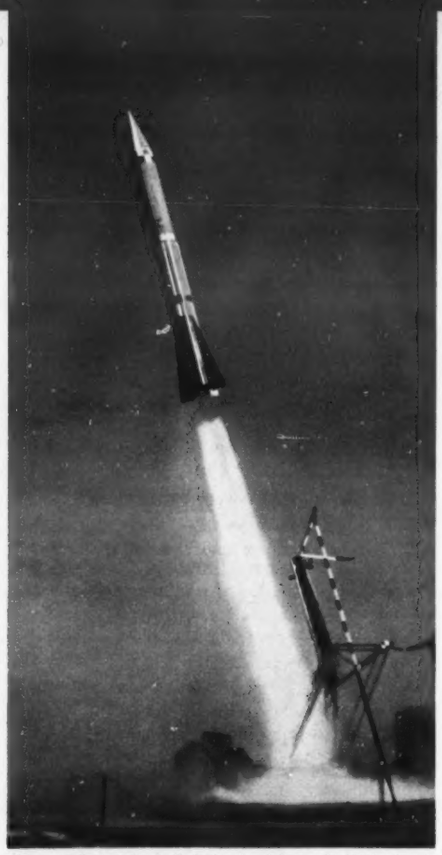
Both sides of the Iron Curtain are at present producing weapons which, it is hoped, will avert a conflict and maintain peace.

Suppose that all atomic weapons are not confined to special strategic formations but that tactical atomic weapons, which can so to speak be tucked under the arm of one or two soldiers and used for shooting at local targets, are issued to battalions. In such a situation, it is difficult to see what basis would be left for disarmament negotiations. Or is the belief seriously entertained that, once these weapons had been widely issued, negotiation could somehow secure their withdrawal?

However this may be, should it be forced into a war started under present conditions which, particularly in Europe, can from the outset be fought only on the defensive, it will not be possible for the West to forgo the tactical atomic weapons which are tabulated here. ←

Atomic, Automatic, Autonomous

The Sergeant Weapons System



An experimental missile being fired from the White Sands range in New Mexico.

Ever since the gun was invented in the late Middle Ages, artillery has been of increasing importance in the art of war. However, it was not until about a hundred years ago that artillery, until then limited to the very front line, was enabled by the development of breech loading to achieve a major increase in its effective range and to operate against enemy supply bases and important communications behind the battle area. Later the aircraft made its appearance in theatres of war and, with its ability to penetrate the rear enemy areas, partially assumed various artillery roles. In order to attack the obviously heavily fortified key points, the aircraft was however obliged to "enter the lion's den" where, despite its mobility, it became more vulnerable than the gun firing from its camouflaged position in the rear. The aircraft was its own means of reconnaissance and could itself report on the accuracy of its own bombing. Against this, tactical air operations were held up by bad weather, in some cases for several days. Moreover, a complex organization was needed to keep the aircraft operational, and airfields, which were difficult to camouflage, provided the enemy with an easy target. Neither artillery nor combat aircraft were in practice entirely capable of complete interdiction of enemy concentration and supply operations; at best they could seriously hinder them.

The advent of the rocket which, armed with a nuclear warhead, forms a highly destructive weapon against which there is so far practically no defence, changed the picture considerably. Any concentration of troops or supplies inevitably falls victim to the first surprise attack. In local as in world-wide conflicts the ground forces must reckon with the possibility that all main lines of communication, or at any rate their most vulnerable parts, such as bridges and railways, will be annihilated at one blow from the attacker. Even the dispersal of troops and the division of units into very small groups can ensure long-term survival only if such groups avoid enemy attacks by continually changing position. For the deadly accuracy of present-day guided missiles in conjunction with high-performance reconnaissance equipment (reconnaissance drones etc.) and telecommunications systems which are virtually immune to electronic counter-measures, have made static warfare impossible.

The tactical requirement for maximum mobility sets the designer of an army guided missile a task whose difficulty increases with the performance required of the weapon as regards payload and range. Here there is a lower limit to the weight of the missile, for the launching weight is roughly proportional to the payload, which in its turn depends directly on the explosive power required; as range increases, so do the weight and volume of the powerplant (motor plus propellant) and the guidance system. Depending on application and state of the art, therefore, the weight of the missile cannot fall below certain limits. But this is only a part of the problem. The missile must be immediately ready for operation on the field, be tested, maintained and repaired, often under extremely difficult conditions, and must not overtax the abilities of operational personnel.

Preparation for launching: The towing vehicle is uncoupled, the turbogenerator started, and the launching platform raised. The launcher is erected, and the outriggers are positioned. In the meantime . . .

. . . the vehicle transporting the missile has arrived. First, the maintenance crew unloads the tail section with the solid-propellant motor. As this is being attached to the launching hooks, two men prepare to fit the centre section, which contains the guidance system. Finally . . .

These were the main problems facing the engineers of the California Institute of Technology Jet Propulsion Laboratory and the Utah Engineering Laboratory of Sperry Rand Corporation when they received a contract some years ago to develop a successor to the Firestone *Corporal*. The new guided missile was to be roughly equivalent to the Firestone rocket in range (80 to 100 miles) and burnout speed (Mach 3+), but to have considerably lower personnel and ground support equipment requirements. To mark its superiority over its predecessor, the new weapon system was given a higher "rank" and was designated *Sergeant*.

The *Sergeant* has two main features which give it a high degree of operational readiness and independence of a costly ground organization: its robust solid-propellant motor and the inertial guidance system. Only four vehicles are necessary for the transport, operational testing and launching of a *Sergeant*, and these, with the exception of the erector/launcher, are all standard army vehicles. As the missile has a launch weight of some 10,000 lb, a length of approximately 35 ft and a diameter of 31 in., it is impracticable to transport it ready assembled; on the other hand, it must not be dismantled into so many parts that it takes too long to reassemble at the launching site. In the case of the *Sergeant* the engineers did not have much difficulty in finding the golden mean. The separation points more or less coincide with the main subassemblies: the tail section with the solid-propellant rocket motor, the centre section with the inertial guidance system, the nose cone with the nuclear warhead, and the stabilization surfaces. Moreover, the launcher determines the minimum size of the vehicles, so that there is no reason for making them any smaller.

Rocket Progress in Figures

	Corporal	Sergeant
Length	46 ft	35 ft
Diameter	29 in.	31 in.
Weight approx.	12,000 lb	10,000 lb
Rocket motor:		
Propellant	liquid	solid
Thrust approx.	20,000 lb	50,000 lb
Guidance system	programme, radio	inertial
Range	80—100 miles	80—100 miles
Burnout speed	Mach 3	Mach 3.5
Time for launch preparation	*several hours	*30 + min
Development began	1946	1954
Production began	1951	1960

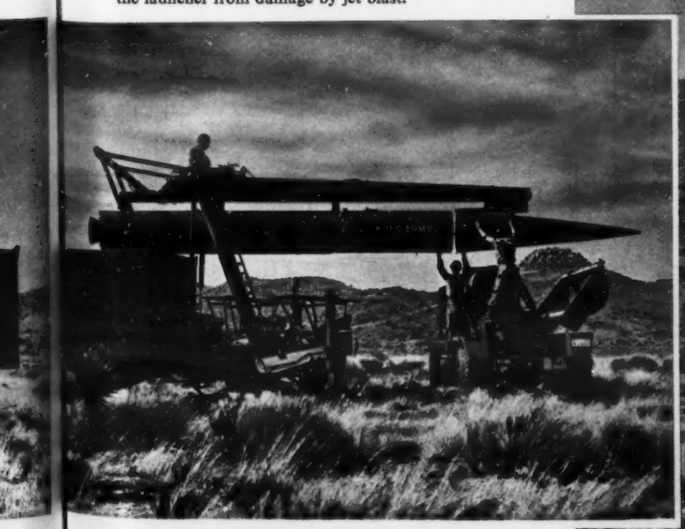
*estimated

All parts of the missile are transported in sealed light alloy containers developed by Temco Aircraft Corporation, which are normally loaded onto trailers but can also be transported by air or on amphibious vehicles. Operational checks on the *Sergeant* components can be carried out without removing them from the containers.

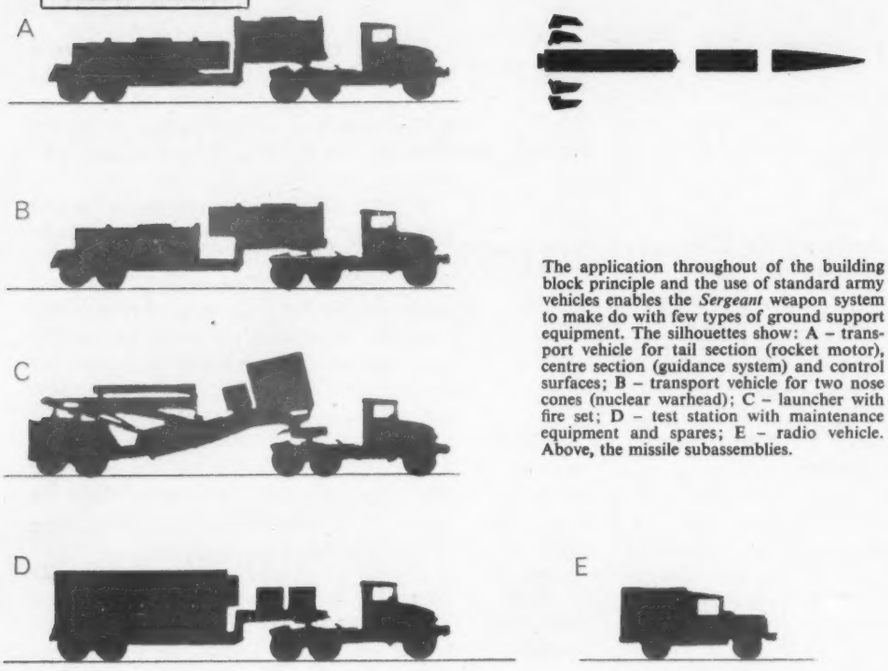
Naturally enough, the U.S. Army has not revealed the time which it takes to prepare the *Sergeant* for launching, but this is assumed to be of the order of 30 minutes. When a battery on the march receives the order to take up a position, it first seeks out a more or less flat area. The launcher is then uncoupled from its towing vehicle and raised into position.

With the aid of a girder which is an integral part of the launcher, the missile can be assembled and raised to the approximate launch position by a few men. An electronic computer calculates the control programme from the coordinates of target and launch positions and from meteorological data (air density, wind) and feeds this information into the missile's guidance system. Once the mission has been ascertained and the order to fire given, the entire launching procedure takes place automatically. Just before the rocket motor fires, the launcher swings to the correct position.

Thanks to its high thrust/weight ratio—the Thiokol Chemical Corporation solid-propellant motor delivers 50,000 lb thrust and the rocket weighs some 10,000 lb—the *Sergeant* does not need to be launched vertically and requires no booster. The cruciform stabilization fins have smaller control surfaces on their trailing edges; there are also control



. . . the control surfaces and the nuclear warhead, which have been transported on a separate vehicle, are fitted (lower picture). The navigation system calculates the direction of launch from the coordinates of the launching site and target position and automatically slews the launcher in the appropriate direction (right). Only when the longitudinal axis of the missile forms an angle of 75° to the horizontal can it be fired. Flame deflectors protect the launcher from damage by jet blast.

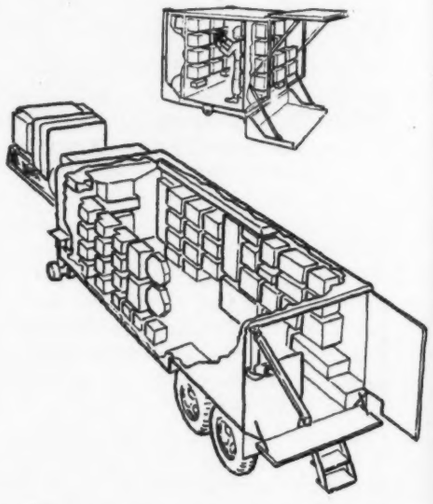


The application throughout of the building block principle and the use of standard army vehicles enables the *Sergeant* weapon system to make do with few types of ground support equipment. The silhouettes show: A – transport vehicle for tail section (rocket motor), centre section (guidance system) and control surfaces; B – transport vehicle for two nose cones (nuclear warhead); C – launcher with fire set; D – test station with maintenance equipment and spares; E – radio vehicle. Above, the missile subassemblies.

vanes which project into the rocket efflux and are actuated by the inertial guidance system to regulate the direction of the thrust within certain limits. Whereas in liquid rocket engines burnout can be programmed for a definite time by closing the propellant feed lines, the propellant charges of solid motors cannot yet be measured or cut off with a sufficient degree of accuracy. As even slight deviations from the correct burnout speed can lead to considerable inaccuracy in hitting the target, the *Sergeant* is fitted with air brakes to perform the task which is entrusted to the burnout valve in liquid-propellant rockets.

In an army weapon system a high degree of reliability can be combined with independence of ground organization only if all maintenance work and minor repairs can be carried out on the spot. Each *Sergeant* battery has its own vehicle, known as an "organizational maintenance test station," to carry out these duties. For the operational testing of a main rocket subassembly, its container is connected with the test station by cable, and a selector switch is set to the appropriate position. From then on the equipment works automatically. If a fault is discovered, the defective part is either replaced on the spot, or the entire subassembly is sent to a "field maintenance test station," which has special equipment for localizing faults which are hard to find and has a comprehensive stock of tools and spares. One field maintenance test station is attached to several batteries. All test stations monitor their own operations.

No defence branch sets greater store by the robustness of weapon systems than does the army. Aboard ship, it is relatively easy to protect missiles against shock and atmospheric conditions; although the launchers are subjected to severe climatic conditions—in particular the action of salt water—weight and space requirements do not play such a decisive role. The army operates under the most difficult conditions; its equipment must work in blizzards, driving rain, sandstorms, arctic cold and tropical heat; violent shocks and vibrations during transport are almost inevitable, dust and mud attack the equipment, and it is exposed to various influences such as atmospheric salinity, vegetable acid, smoke, insects etc. No wonder, then, that Sperry not only subjected all parts of the *Sergeant* weapon system to rigorous mechanical tests, but exposed them to all imaginable kinds of meteorological conditions in climatic test chambers. In addition to the missile itself, the transport vehicles, launcher and mobile test stations were tested. Launch preparation, missile assembly, operational tests, maintenance—all the procedures necessary during actual operation were repeatedly rehearsed in the climatic chambers.



In the fire set (above) and the test station the equipment consists of easily interchangeable modules.

Only a high degree of independence of terrain can provide the necessary mobility for artillery. This towing vehicle with trailer is designed as a test station and spares depot and serves to a certain extent as a "maintenance centre" for a number of *Sergeant* batteries.

JPL, Sperry and the more than 3,000 subcontractors have good reason to be satisfied. According to official reports, the *Sergeant* has proved its reliability in dozens of test firings over the White Sands missile range. A few weeks ago the Sperry Utah Engineering Laboratory received a $16.8 million contract for quantity production, and there can be no doubt that this will be followed by others before the *Sergeant* is superseded by a new weapon system—perhaps with the rank of *Lieutenant* or *Captain*.

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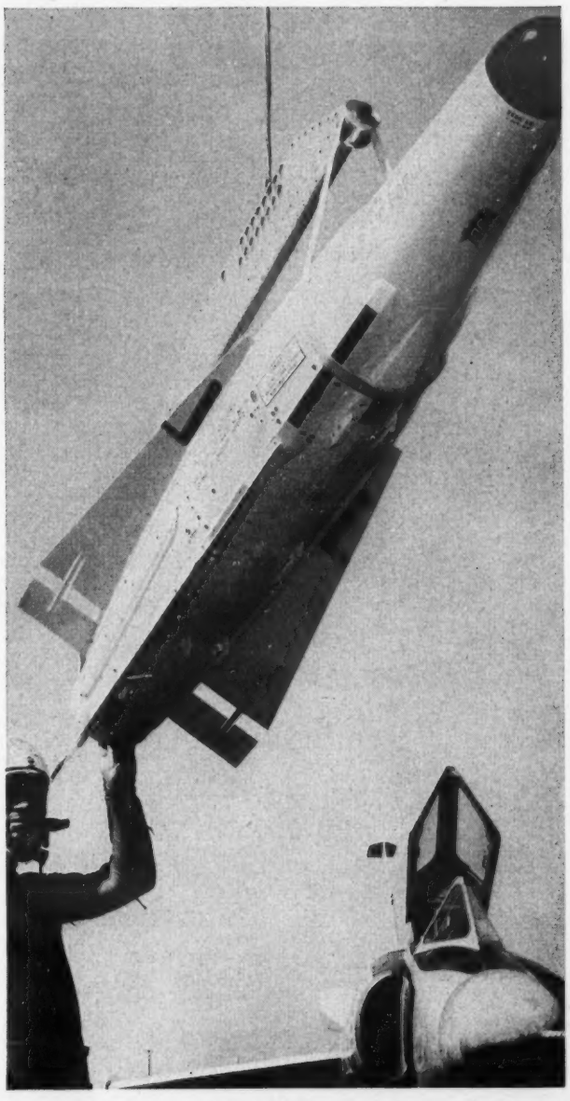

Larger than earlier Falcons, yet small considering its extended capability, the new Falcon is 7 feet long, 11 inches in diameter and weighs slightly more than 200 pounds.

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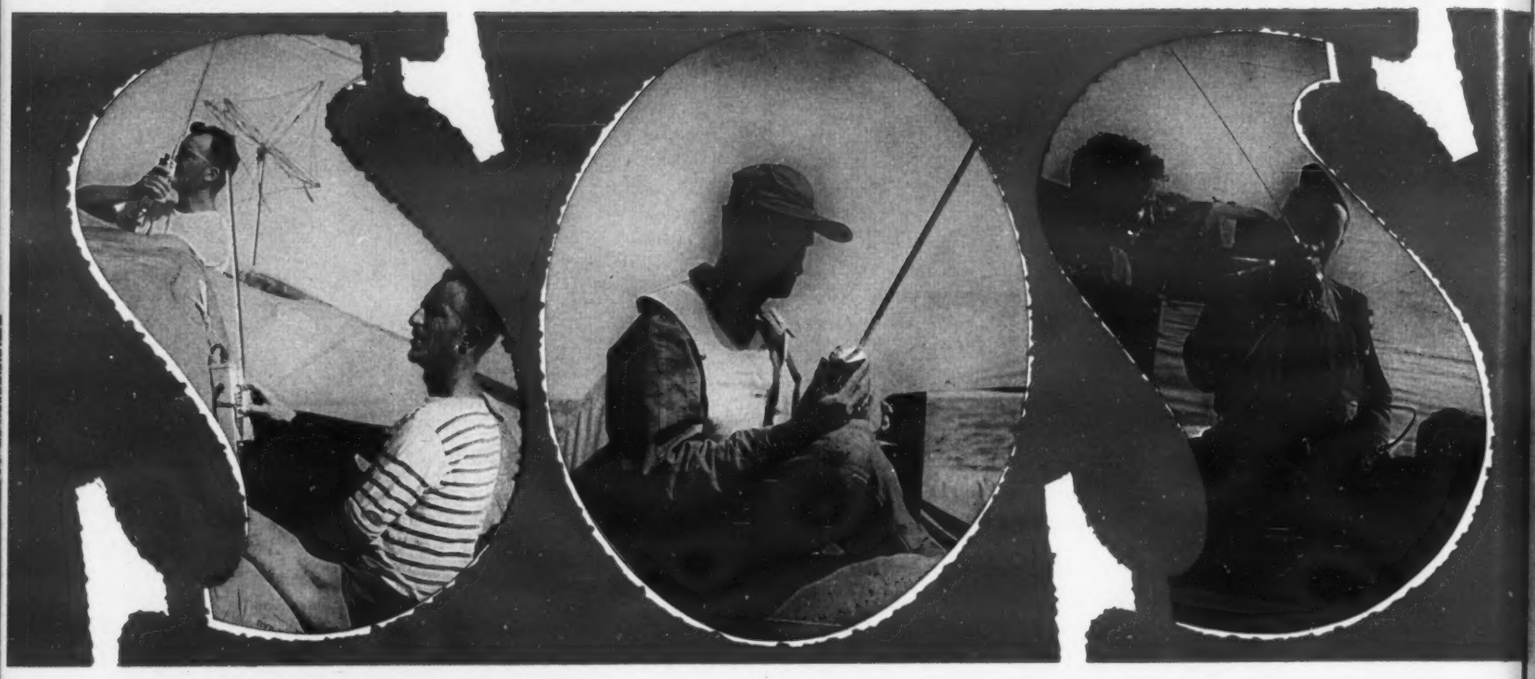

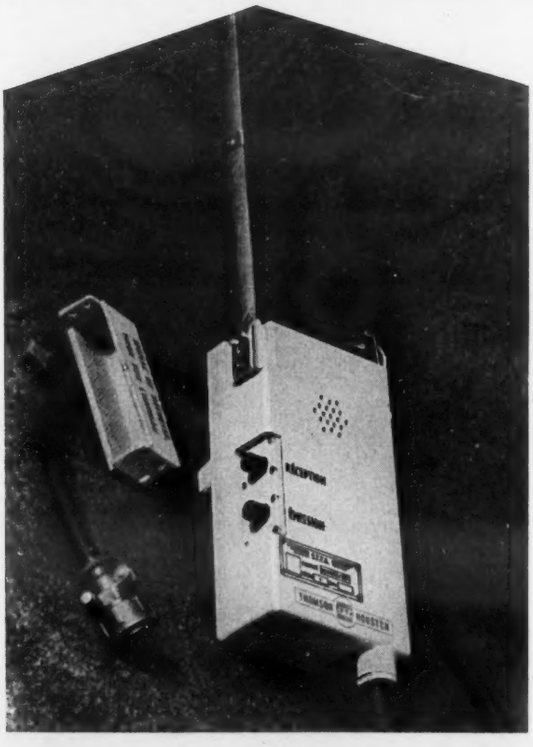

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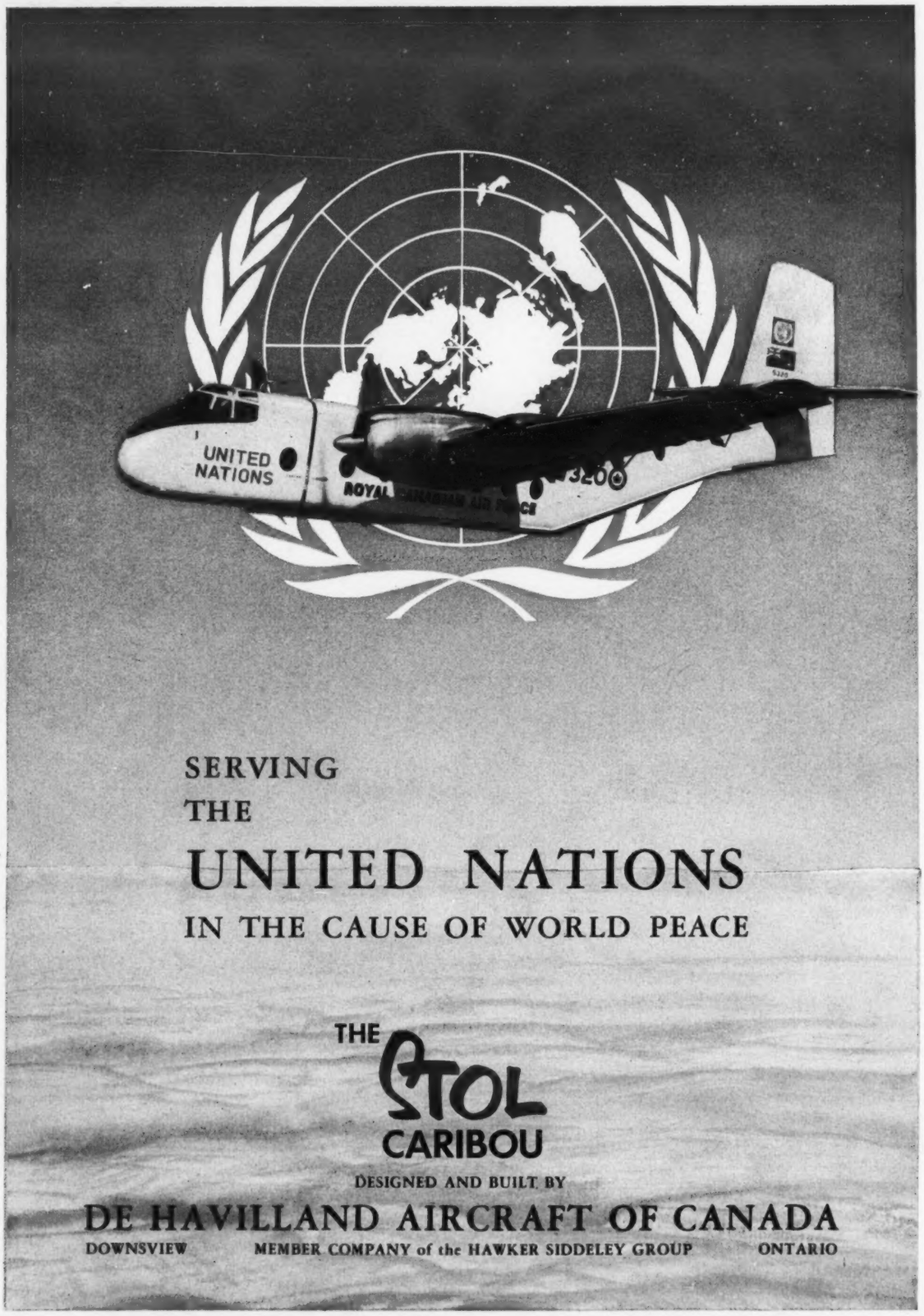

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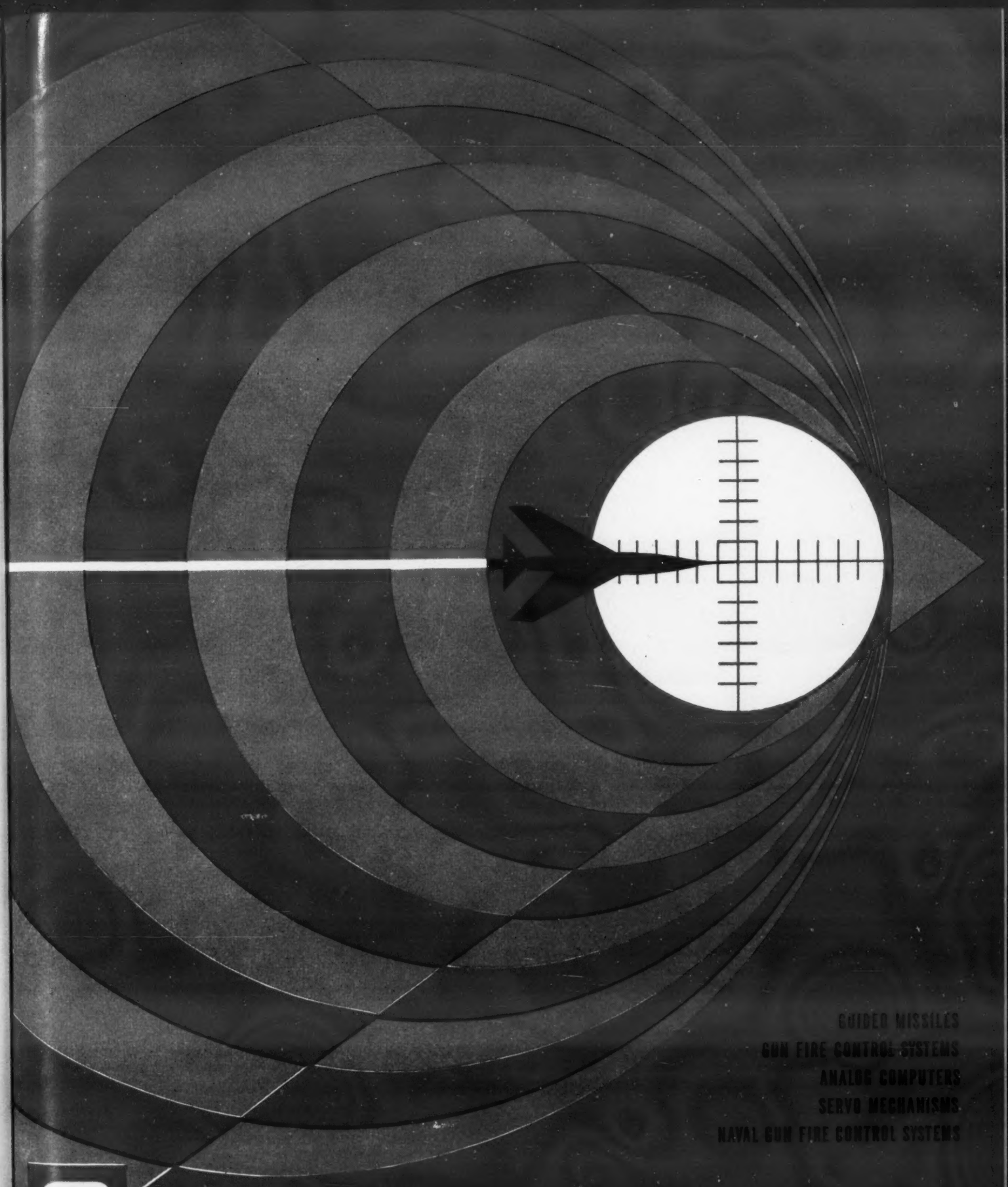

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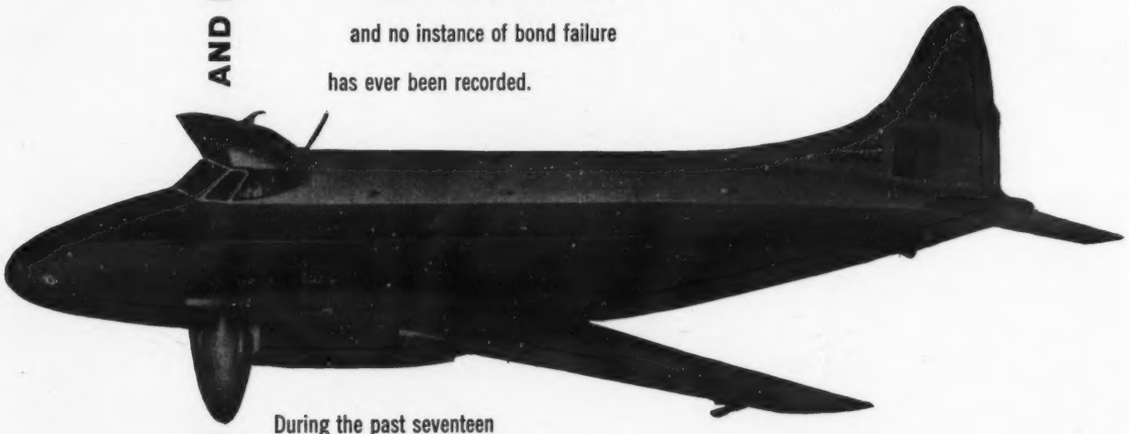

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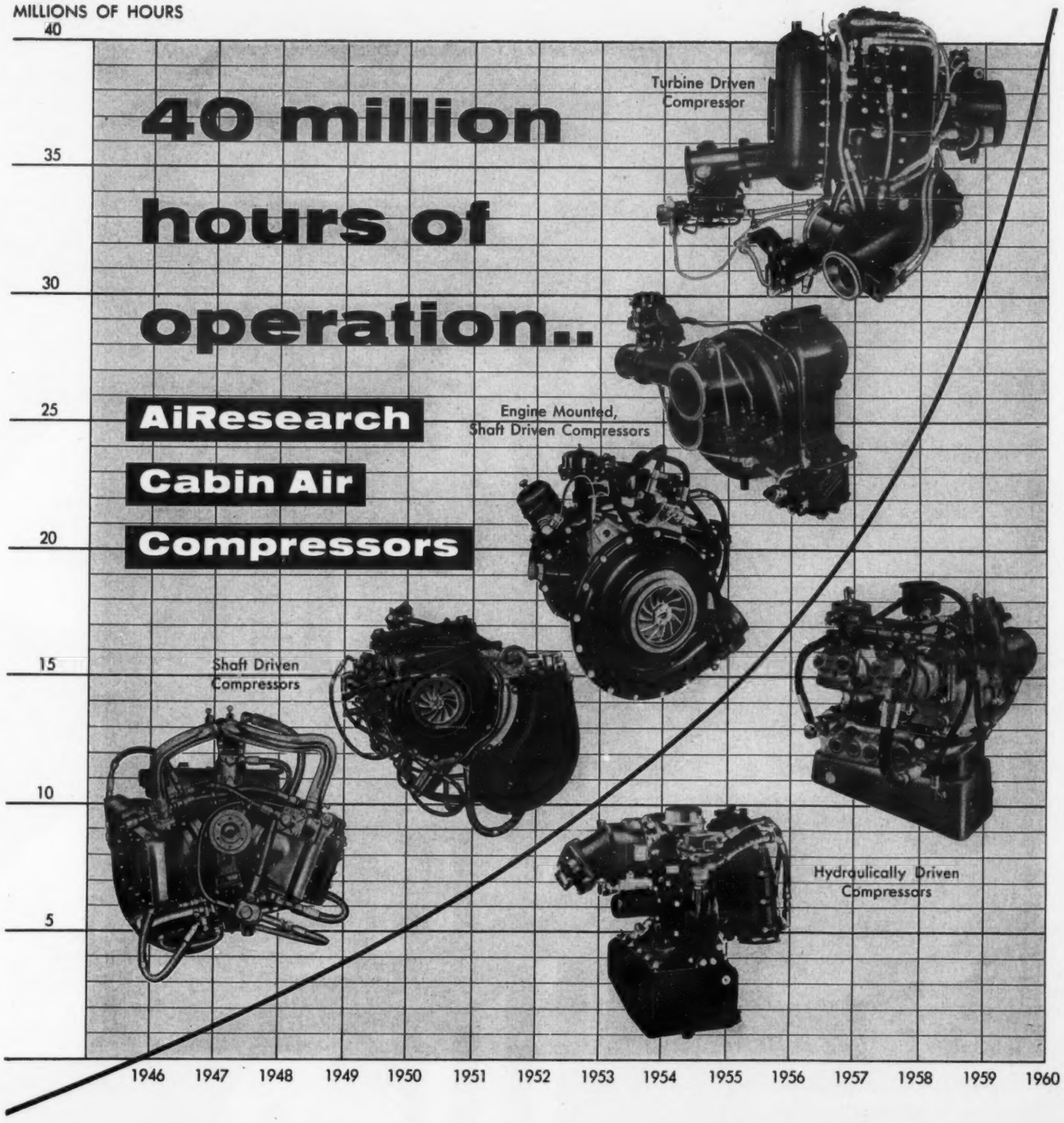

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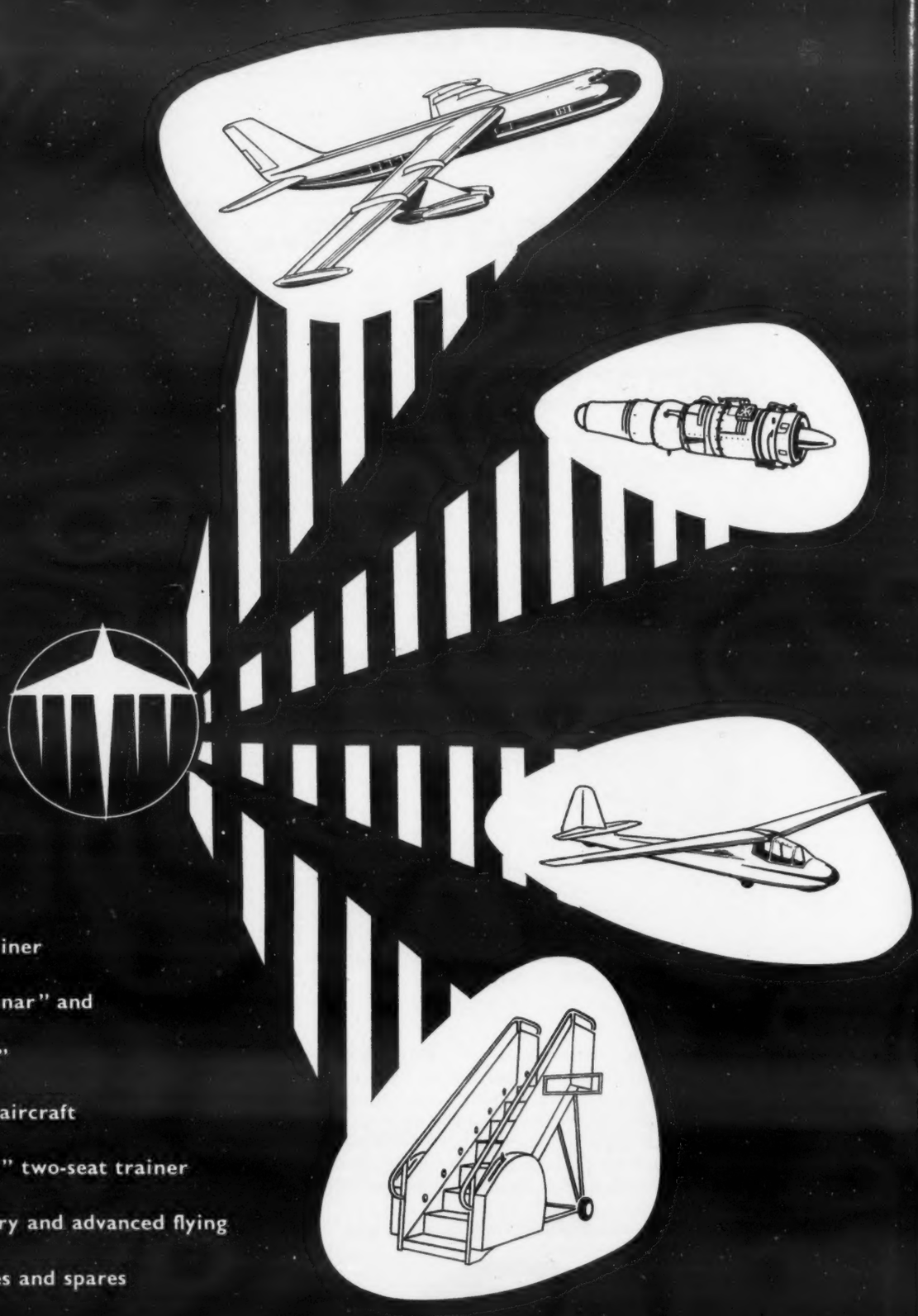

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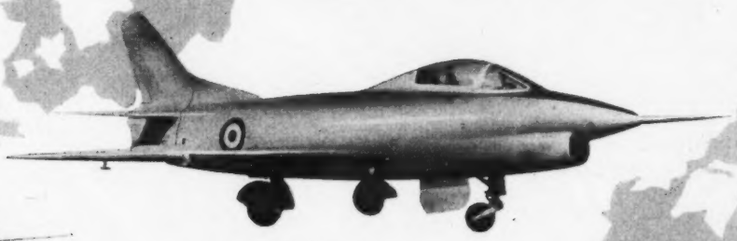

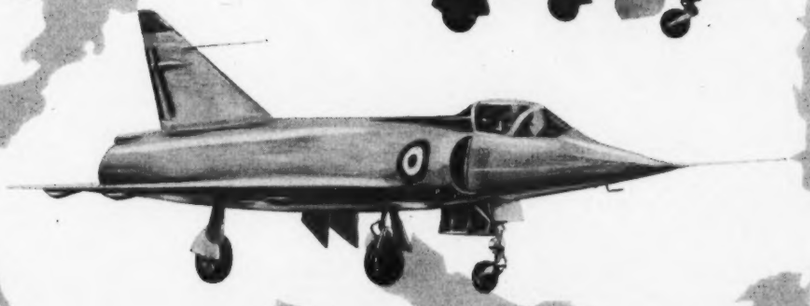

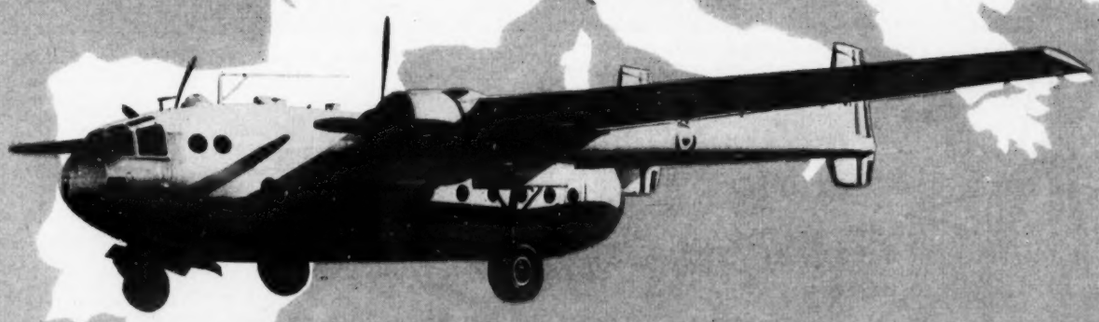

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Only a few years ago the West's arsenal of tactical guided missiles for combat zone operations consisted of a handful of types, but today there are over 50 different models which replace the entire range of conventional artillery and reflect the advent of entirely new weapon categories. At the beginning of the fifties the U.S. Army hoped to get by with the *Redstone* with its range of 200 miles, the smaller *Corporal* with a range of 75 miles and the *Honest John* short-range artillery rocket. Today there is a special guided missile for every purpose—from the destruction of targets 600 miles away to anti-tank warfare. Although this may involve a certain fragmentation of military funds, there can be no overlooking the fact that these weapons can perform the tasks of a vast number of conventional ones whose operation required far greater numbers of personnel. Moreover, tactical rockets have become simpler and cheaper and can be produced in sufficient numbers to equip all independently operating units.

It is outside the scope of this article to give a complete catalogue of tactical rockets, as this would include not only a score of anti-aircraft rockets but also countless surface-to-surface missiles, guided and unguided air-to-surface missiles, dozens of air-to-air missiles and special anti-tank and anti-submarine weapons. A few examples will show how altered tactical concepts—massive striking power in the hands of nuclear divisions split up into small, highly efficient units—have imposed the creation of completely new guided missile systems, and how new developments in the guided missile sector have led to sweeping changes in military planning.

Where formerly runways had to be built for the aircraft which were to destroy the targets in the enemy's rear areas, and vast supply organizations were necessary for these vulnerable airfields, mobile rockets with ranges of a few hundred miles can now be used. These can be transported, together with their ground support equipment, by three or four vehicles and can in a few minutes do as much damage to the enemy as weeks of air attacks.

Moreover, it is now possible, by miniaturizing nuclear warheads on the one hand and developing cheaper and more reliable rocket powerplants and guidance systems on the other, to provide atomic weapons for small infantry units and aircraft operating singly. In the *Davy Crockett*, for instance, the American infantry will have a weapon which, though operated by only two men, will equal a number of heavy artillery batteries in fire power.

What are these new army guided missiles like and how are they operated?

Leaving aside longer-range guided rockets such as the *Sergeant* and *Pershing* (with 20 kiloton warheads), the ground forces' tactical guided missiles of tomorrow fall into the following main categories.

1 – *Artillery rockets for the support of front-line troops.* These weapons are generally intended for use in the vicinity of the combat units themselves and must therefore be highly mobile; they operate under the most severe conditions, such as those characteristic of a nuclear battlefield. Their range is between 6 and 200 miles, and they are transported and operated by four to six men. Typical examples are the XM-51 *Little John* and M-51 *Honest John* unguided artillery rockets, and the *Lacrosse* guided missile—all operational with the U.S. Army—and the multi-purpose *Missile A* developed under contract to the U.S. Army.

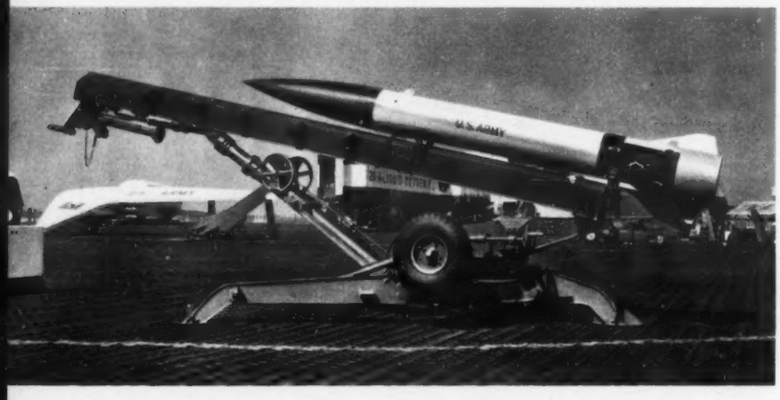
2 – *One- and two-man weapons for anti-tank operations and operations against fortified positions.* These weapons, which are designed for front-line operations, have ranges of 1,000 to 5,000 yards and can be transported by infantrymen or on light vehicles and trailers. Typical representatives of this category are the French SS.10 and SS.11, the German *Cobra*, the American XM-72 *Lawman*, larger, longer-range guided missiles such as the SS.12 (France), *Malkara* (Australia) and *Shillelagh* (USA), and the *Davy Crockett* unguided nuclear rocket, the latest addition to the U.S. Army's arsenal.

3 – *Rockets for the destruction of low-flying enemy strike aircraft and tactical guided missiles.* These weapons, which operate over shorter

The Martin *Davy Crockett*, the U.S.Army's latest tactical nuclear weapon, is launched from a recoilless tube mounted on a jeep. Picture on left shows the football-sized nuclear warhead, whose rocket motor is inserted in the launching tube. The launcher is operated by two men. The U.S.Army is reportedly considering at least two different versions of the *Davy Crockett* which, fitted with a nuclear or high-explosive warhead, has a range of three to five miles.

A Martin *Lacrosse* remotely guided surface-to-surface missile ready for firing from the launcher of its transport vehicle.

The U.S. Army's *Little John* short-range artillery rocket is fired from a mobile launcher which can be erected in a very short time.



ranges, must be largely self-contained, i.e., they must have their own detection, target tracking and guidance radar, and must be highly mobile and ready for launching at any time in order to give the army units which they support effective protection against enemy attacks from the air. Typical representatives are the American *Hawk* anti-aircraft rocket and the British *Tigercat*. The most modern weapon system of this category is the U.S. Army's *Mauler*.

4 – *One-man anti-aircraft weapons for operations against low-flying frontline aircraft*. This is a task which was formerly the province of light-calibre machine-guns. The sole representative of this category so far is the U.S. Army's *Redeye*, with infra-red homing head, which can be fired from a shoulder launching tube.

Air forces, too, will be equipped with special weapons for use against tanks, fortified positions and tactical radars, but there is no space in this present article for a list of these air-to-surface weapons.

*

Unlike the 100 mile range *Sergeant* described in the previous article and the *Pershing* with its range of 300 miles, which require a number of vehicles to transport the weapons and their ground support equipment, most of the missiles dealt with in the following pages can be transported by a single vehicle or even by an infantryman and can be fired immediately without appreciable preparation.

The *Lacrosse* guided missile, produced by the Orlando Division of The Martin Company, is specially designed for the destruction of fortified installations and for this purpose carries a nuclear warhead of several kilotons explosive force. It can be guided to its target by radio operated from a forward position; the missile and vehicle crews and the launching platform can therefore remain 6 to 12 miles behind the front line and are hence less exposed to enemy fire. A detailed description of the *Lacrosse* was published in *Interavia* No. 11/1958 (pp. 1162 et seq.).

To fire the *Little John* and *Honest John* unguided artillery rockets, however, the missile crew must have precise information on the position of the target, before they train the launchers onto it. The M-31 *Honest John* is operational with the U.S. Army in Europe and Japan and with the fighting forces of a number of NATO States and can transport a 1,500 lb conventional or nuclear warhead over a distance of 12 miles. The *Honest John* is fired from a heavy multi-axle launcher, but the *Little John* (XM-51) can be launched from a relatively light single-axle launcher which can be attached to a variety of army vehicles. The Army Rocket and Guided Missile Agency developed the *Little John*, and Hercules Powder Co. supplies the combined booster/cruise powerplant; the rocket airframe is built by Emerson Electric Manufacturing Company. The XM-51 and its launcher, together with the remaining ground support equipment, weigh some 2,500 lb and can be transported by helicopter. While the *Lacrosse* can be accurately guided to point targets by an operator in a forward position, the unguided *Little John* and *Honest John* are nuclear warhead carriers of moderate accuracy for operations against dispersed targets.

With a view to standardizing the U.S. Army's rocket arsenal and reducing the number of types, the three missiles just mentioned—*Lacrosse, Honest John* and *Little John*—are to be replaced by the projected tactical *Missile B*, which is to have a launch weight of roughly 1,000 lb and to transport a small 5 kiloton nuclear warhead over a range of 3 to 30 miles. Army planners are evidently trying to make these new weapons as simple as possible, operating them as unguided missiles (i.e., without radio control or inertial guidance system) while still, however, retaining stabilization to enable the missile to maintain its course.

The simplest nuclear rocket so far is the *Davy Crockett*. Powered by a solid-propellant motor and spin-stabilized by unfolding fins, it can attack targets at distances of up to 5 miles, travelling on a relatively flat trajectory. The U.S. Army Ordnance Corps has developed two launching systems, both consisting of a tube for recoilless firing, though one is slightly heavier and has an additional charge to accelerate the missile from the tube. This will increase the *Davy Crockett's* range over the normal 5 miles. Both launching devices can be transported on jeeps, anti-tank vehicles or other small vehicles, and can be operated by two men. The smaller *Davy Crockett* launcher can actually be carried and set up by two men. The U.S. Army has requested funds for the procurement of over 6,000 *Davy Crocketts* during the current fiscal year.

The Aeronutronics System Division of Ford Motor Company is working on a small guided weapon, named *Shillelagh*, which can be fitted with a nuclear warhead for operations against armoured vehicles, troop concentrations and fortified positions. Raytheon is subcontractor for the guidance system. With a weight of 45 lb and a

XM-72 is the designation of this new American weapon for anti-tank operations. Of extremely small dimensions and carried in a combined transport container/launching tube, it can be fired by an infantryman from a standing, kneeling or prone position. It has enough power to penetrate armoured vehicles and small fortifications. Lower right: rocket-powered weapon with folding stabilization surfaces, together with the transport and launching container with firing and aiming device and shoulder-strap.

calibre of 90 mm, the *Shillelagh* is fired from a simple launching tube and is then accurately guided to its target by a microwave radio guide beam aligned with the aiming device.

Little is yet known of the new XM-72 *Lawman* anti-tank weapon. It is aimed at the tank by means of an optical sight and is spin-stabilized by fins which open as it begins its flight. The telescoping launching tube can be extended before firing, to give the weapon greater directional accuracy. The missile is remarkable for its small dimensions and the low weight of the explosive charge (only a few pounds). The main contractor for the XM-72 is the Hesse Eastern Division of Flightex Fabrics Inc., and the Army Ordnance Missile Command is the weapon system coordinator.

A particularly thorny problem is defence against low-flying strike aircraft operating against ground forces and using the most advanced weapons, including small nuclear bombs. Added to this is the ever-present danger of enemy ballistic missile attacks, against which there has until the present been no defence. Under the U.S. Army's modernization programme the Convair Division of General Dynamics has developed an all-weather air defence system with the name *Mauler*, which is equipped with relatively small rockets for operations against both aircraft and missiles. The *Mauler* weapon system is mounted as a complete unit on an M-113 armoured chassis built by the Food Machinery and Chemical Company and comprises a swivelling launch unit with twelve launchers and rockets, a target detection and fire control radar with four gyro-stabilized antennas and compact fire control computer, plus power supply and operational testing equipment. The *Mauler* can be launched while the armoured chassis is in motion, and the entire system requires only one operator. The 8 ft rocket is transported in light containers, which at the same time serve as launching tubes for fitting to the launcher. All components of the launching system are transportable by aeroplane or helicopter and can be parachuted into the combat zone. The Army Rocket and Guided Missile Agency is coordinator of the weapon system, and Grand Central Rocket Co. is responsible for the development and production of the motor. Hughes Aircraft Co. is developing the guidance system.

So far the smallest anti-aircraft system in the world, the Convair *Redeye*, a 4 ft rocket with infra-red homing head, can be fired from a simple, light launching tube which also serves as transport container. This one-man weapon is designed primarily for defence against low-flying fighter-bombers and reconnaissance aircraft, but its homing device enables it to detect and destroy other heat sources such as vehicles, diesel power units etc.

The *Malkara* wire-guided surface-to-surface missile (main contractor Government Aircraft Factories, Melbourne, Australia) is designed for operations against tanks and fortified positions, can be fired from vehicles of all kinds.

The latest short-range guided missile developed by Nord-Aviation for combat operations, bears the designation SS.12. Originally designed for wire guidance, the SS.12 is now to be radio-guided, enabling it to operate over longer ranges and at higher speeds.

The highly mobile *Mauler* weapons system (prime contractor Convair Pomona) is designed to destroy artillery rockets and other tactical guided missiles as well as low-flying enemy aircraft in the combat zone. Installed in a special armoured vehicle, the M-113 (see picture), the missile would be fired from a launching device which would also serve as a transport container. As the picture shows, each vehicle carries 12 launchers, which are combined to form an erectable launching unit. The launch vehicle is equipped with a radar mast on which are mounted two Raytheon gyro-stabilized search antennas. The launching unit also carries two further Raytheon antennas for target tracking.

The Convair *Redeye*, the smallest anti-aircraft weapons system in the world, consists of a 4 ft rocket with infra-red homing head (in hands of officer in picture), the launch tube which also serves as a transport container, and the butt. The complete weapons system weighs only 20 lb, is ready for instantaneous launching and can also be used against other heat-generating targets.

It is still too early to evaluate the consequences of equipping a modern pentomic division with one-man anti-aircraft rockets of this kind. It is possible that the mere presence of such small weapons would deter a potential aggressor from making low-level penetrations into the combat zone. At higher altitudes, however, he would inevitably fall victim to other anti-aircraft weapons and to the air defence forces, which would receive timely warning by radar.

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Of course, many of the guided nuclear weapons mentioned in the present article can also be used with conventional warheads. For in many cases it is impracticable for the defender to contaminate the territory with radioactive fallout—particularly if the civilian population remaining in the area may be endangered. Be that as it may, the very threat of tactical nuclear weapons means that a potential aggressor will have to take a completely new course of action. However great his superiority of force, an aggressor who takes action against an army equipped with tactical nuclear weapons of all calibres is running an incalculable risk. ←→

The Falcon Family

A History of Guided Aircraft Rocket Development

The missile armament of the F-102A *Delta Dagger*. Here the load consists of three radar and three infra-red guided *Falcons* together with 24 FFAR (Folding Fin Air Rockets) in the launching tubes.

The pattern of offensive and defensive tactics employed by the attacking interceptor and the bomber aircraft has undergone radical changes during the past ten years.

For the bomber aircraft, the day of the mass attack is past when the formation acted as a defensive unit enabling the massed firepower of the defensive guns to be brought to bear on the attacking fighter. Today the bomber relies upon its speed and high flying capability for its defence, and the explosive power of a nuclear bomb makes the employment of large formations unnecessary if a target is to be destroyed in a single attack.

In consequence the interceptor aircraft is faced with a far more difficult problem. The margin of speed advantage possessed by the fighter is far smaller, and the time required for detection of the bomber, positioning for the attack and finally carrying out the attack has been greatly reduced.

Faced with this problem, it is only natural that military planners have sought other means to increase the potential of the interceptor. The pattern that has been followed is illustrated by the development of the *Falcon* missile by Hughes Aircraft Company.

Work commenced on this project in 1947, and in 1949 an experimental air-to-air radar-guided missile with a solid-propellant rocket motor began flight trials. These trials culminated in the production of the operational *Falcon* GAR-1, which was taken into the inventory of Air Defense Command in 1954.

The history of this missile over the succeeding years has been one of continuous development to meet changing tactical and operational situations. The first *Falcon* was modified in 1956 to the GAR-1D, basically the same missile as the original, but with slightly larger control surfaces to improve its performance at high altitude.

In mid-1956, these two radar-guided versions were joined by the GAR-2, which was the first infra-red seeking *Falcon*. With the exception of the nose cone, the external configuration was similar to that of the radar-guided versions.

The continuing demands for greater speed, longer range, higher combat ceiling and a more powerful and destructive warhead, led to the introduction of the GAR-3 *Super Falcon*. This missile was fitted with a more sensitive semi-active radar guidance system and approximately 300 units were built before being superseded by the GAR-3A.

The GAR-3A is powered by a solid-propellant rocket motor which produces two levels of thrust. A high power thrust launches the missile and accelerates it to maximum speed, a lower level thrust then maintains the missile velocity.

Previous experience with infra-red seeking homing devices enabled Hughes to develop the GAR-4A with an advanced infra-red detector which enables it to lock-on to smaller targets at greater ranges than early infra-red missiles.

In the spring of 1960, a new chapter in the development of the *Falcon* was opened by the introduction of the Super Falcon GAR-11. This intricate but compact weapon represents the new generation of Hughes air-to-air missiles and combines the precision guidance and homing of its predecessors with the explosive power of a nuclear warhead.

The nuclear *Falcon* is only slightly larger than the earlier missiles of the series. It is 7 feet long, 11 inches in diameter and weighs slightly over 200 pounds. Its greatly increased explosive blast enables the interceptor to carry out head-on and frontal attacks against enemy bombers with a greatly increased probability of success. Because of the high rates of closing speed, the delivery of an attack from a point ahead of the bomber has always been difficult. The time available for target detection, aiming, missile launch and breakaway is so reduced that the guidance systems are not always capable of achieving the pinpoint accuracy necessary for a hit with a conventional high-explosive missile.

Radar guidance was chosen for the GAR-11 nuclear *Falcon* to enable attacks to be made from head-on, and the sensitivity of the system is sufficiently high to enable the GAR-11 to lock-on to a target at least 30° from dead ahead. According to the manufacturer the semi-active radar guidance is largely immune to enemy countermeasures to deflect the trajectory of the missile.

Owing to the increased weight and size of the GAR-11, its speed performance is lower than that of its predecessors. This is offset by the increase in the lethal blast area of its warhead and its employment in head-on attacks. In operational conditions an interceptor aircraft would normally carry a mixed load of conventional high-explosive and nuclear armed missiles for use as conditions dictated.

*

The successful performance of an air-to-air missile is not dependent entirely upon the design of the missile itself. A complex search and tracking programme must be carried out to position the launch aircraft at the point from which the missiles can be released with the maximum possibility of success.

The development of the *Falcon* series of missiles has moved in step with the advances in fire control systems. The E-1 system, developed by Hughes

A test cradle simulates the vibrations encountered by a *Falcon* missile when carried on the wing of a fighter aircraft. Shock tests are carried out in the bottom of the test cradle.

for two-seat interceptors such as the subsonic F-89, required the assistance of the radar observer to carry out the attack. This early type of fire control system consisted of an automatic search and tracking radar, an optical gunsight and a computer which calculated the aim off for deflection shooting. As the interceptor approached the target, the radar scanned the area ahead and fed the target echo to the observer's scope. The observer then locked the radar on the target, and the E-1 system continuously measured the target's range, azimuth and elevation.

After the radar lock-on, the pilot commenced the attack by steering the aircraft toward the target either by reference to the optical gunsight or the radar display. A signal on the radar scope indicated when the aircraft was in firing range and pilot opened fire.

Many of the features of the E-1 system were employed by Hughes in the development of a satisfactory rocket aiming system. Modifications to the computer enabled the equipment to compute an intercept course and also to fire the rockets automatically.

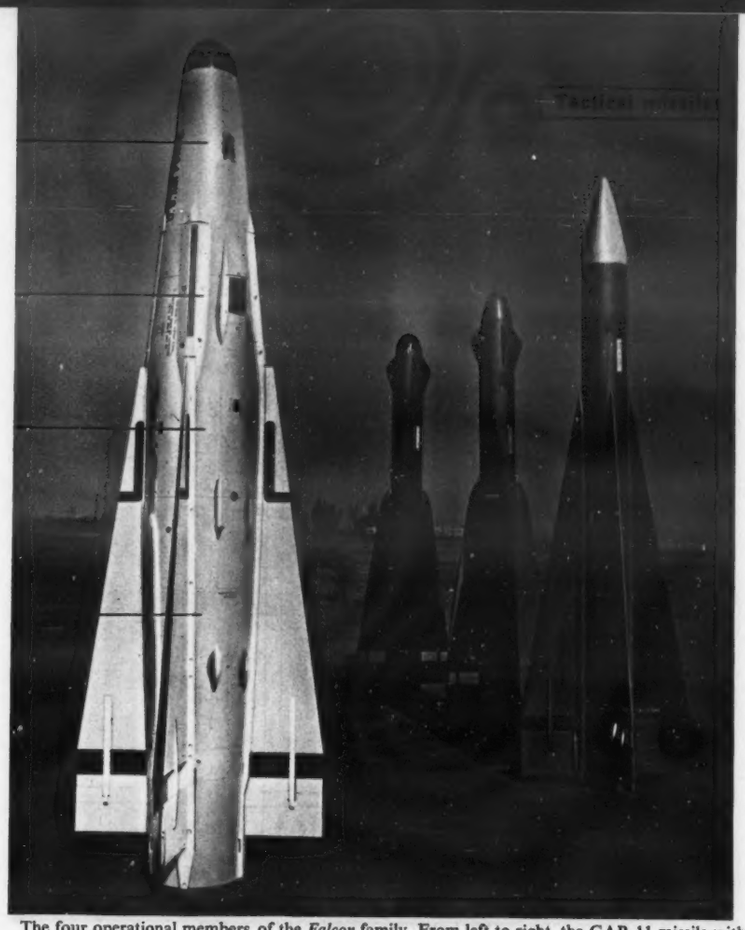
The E-4 was the first production system for rocket firing interceptors and was designed for one-man operation. The radar was five times more powerful than preceding systems and also provided ground beacon interrogation and ground mapping facilities. As the *Falcon* missiles became operational in the North American Air Defense Command, Hughes engineers developed the E-9 system which extended the capabilities of the basic control system to meet the firing requirements of the *Falcon* missiles.

During this period the F-102A *Delta Dagger* was coming into service with NORAD. For a considerable time a cooperative design progamme had been carried out between Hughes and Convair to install an advanced fire control system in this all-weather interceptor, and in consequence the aircraft entered service fully equipped with the compact MG-10 system.

Apart from providing a one-man fire control unit, the MG-10 also incorporates a data link receiving subsystem and automatic flight control. The data link receives control commands from ground stations and displays this information on the pilot's radar scope and instrument panel. These commands include heading to fly, the time-to-go until attack, and the range, azimuth and elevation of the target. The automatic flight control links the aircraft's control surfaces to the MG-10, maintaining any heading, pitch and altitude established by the pilot.

This automated system has now been refined into the MA-1, built for the Convair F-106A *Delta Dart*. On an interception the MA-1 takes control of the aircraft, flies it out to meet the target, launches the attack and brings the interceptor back to base.

The combination of an automated system such as the MA-1, and target-seeking missiles of the *Falcon* type represents the latest and most advanced stage in the continuous battle between defence and offence as exemplified by the relative capabilities of the interceptor and high-flying bomber. ←→



The four operational members of the *Falcon* family. From left to right, the GAR-11 missile with nuclear warhead, the radar-guided GAR-1D, the infra-red-guided GAR-2A, and the radar-guided GAR-3 *Super Falcon*.

Designation	GAR-1	GAR-2A	GAR-3A	GAR-4A	GAR-11
Diameter	6.4 in.	6.4 in.	6.4 in.	6.4 in.	11 in.
Length	6 ft 6 in.	6 ft 6 in.	7 ft 1 in.	7 ft 1 in.	7 ft
Weight	110 lb	121 lb	150 lb	150 lb	200 lb plus
Speed *	M2+	M2+	M3	M3	M2+
Range *	5 mi	5+ mi	6 mi	6 mi	4+ mi
Guidance	Radar	Infra-red	Radar	Infra-red	Radar
Warhead	H.E.	H.E.	H.E.	H.E.	Nuclear

* approx.

A shipment of *Falcon* missiles awaiting acceptance by the Air Force. Production to date has exceeded 30,000 units and includes over 4,000 GAR-1, 12,000 GAR-1D, 9,500 GAR-2A, 300 GAR-3 *Super Falcons*, 800 GAR-3A and over 100 GAR-11 nuclear *Falcons*.

Radioplane Target Drones in Operation

The Radioplane XQ-4 target drone reaches a maximum speed of Mach 2.

The unforgiving nature of modern warfare will allow little, if any, opportunity to modify in battle the performance of the men and machines which must fight it. The readiness of the forces and their weapons must be thoroughly tested and proven to the maximum degree technology and economy permit before they are called upon to meet the sudden, swift challenge of atomic-age combat.

In the areas of air defense and air-to-air war a major portion of this requirement is satisfied through the use of target systems simulating an enemy aircraft or an enemy missile. As, however, modern surface-to-air and air-to-air weapons have progressed well beyond Mach 1 and to altitudes in the vicinity of 100,000 ft, high-performance target systems such as the rocket-powered RP-76 and the Q-4 type produced by the Radioplane Division of Northrop Corporation have been developed to evaluate the capabilities of such weapons and to maintain the proficiency of missile crews.

RP-76 target drone system

The Radioplane Division of Northrop, which has been building target and surveillance drone systems since 1938 for use by all branches of the United States armed forces and the military forces of many free world nations, has produced the subsonic and supersonic RP-76 for the U.S. Army. The drone requires minimum logistical support, facilities and manpower; it can be recovered or expended as the mission and the operating conditions demand.

The U.S. Army has already ordered 1,470 RP-76s, which are compatible with both the *Nike-Ajax* and the *Nike-Hercules* surface-to-air missiles. The RP-76 is used regularly at McGregor Range, Fort Bliss, Texas, for weapon system training and evaluation, annual service practice firing and the training of *Nike* missile crews of NATO nations. It is also used train NATO troops on the Raytheon *Hawk* anti-aircraft rocket.

A *Nike-Hercules* missile fired by U.S. Army Air Defense Command troops at McGregor Range, Fort Bliss, recently scored a direct hit on an RP-76 target missile at an altitude of 55,000 ft. The supersonic target was intercepted while flying at a speed of Mach 1.15. This is the highest and the fastest target which has ever been intercepted by Army Air Defense Command troops during annual service practice.

Speeds of Mach 1.25 and altitudes of 66,000 ft were attained by the RP-76 during operational flights, using the new 100 lb thrust engine which now powers standard target missiles being produced in quantity for the U.S. Army. Using the same engine, the RP-76 has attained record altitudes in excess of 75,000 ft.

Flight endurance in the subsonic configuration covers two conditions, rocket-powered flight for nine full minutes, and glide flight after burn-out, which gives a total usable flight time of up to 30 minutes depending on the mission altitude. The primary purpose served by limiting the powered phase of flight to nine minutes is to reduce cost per unit and cost per mission, which are almost entirely dependent on the length of the powered phase. If this were extended to include the stand-by time for scramble, acquisition, cruise and positioning, costs would rise sharply. Research by Radioplane engineers has revealed that a powered phase of 9 minutes is sufficient for simulating combat conditions with current and future weapon systems.

The Radioplane RP-76 target drone can achieve maximum speeds of Mach 0.94 to 1.25 according to version.

The RP-76 system comprises . . .

the target drone itself, a carrier aircraft, various airborne and ground support equipments, command control and tracking aid equipments and test instruments. The target vehicle itself is fabricated almost entirely of non-strategic materials: laminated fibreglass for the fore and aft fuselage, aluminum honeycomb and aluminum skin for the wing. The rocket engine casing is used as the center of the fuselage with the fore and aft sections snugly fitted to it. The wing is also attached to the engine casing by means of

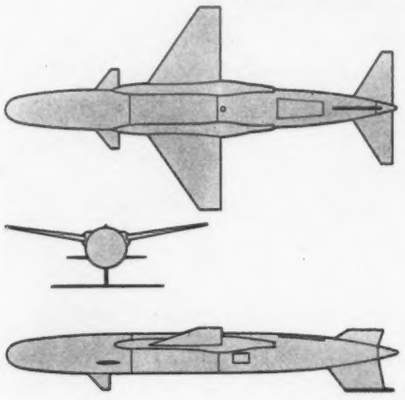
wing fittings and attach pins. This manner of construction provides for low cost unit output, at the same time giving increased strength-weight ratio and stiffness.

...airborne equipment

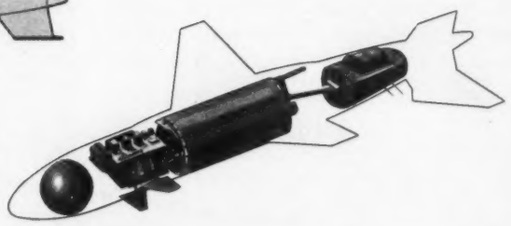
Although small and light in weight, the RP-76 readily accommodates all equipment required for a variety of missions. Passive radar augmentation is furnished in various configurations as required by the interception method employed: the L-band augmenter for GCI, the Luneberg lens and X-band monostatic augmentation for air interception, and X-band bi-static augmentation and traveling wave tube equipment for missile radars. Infra-red flares can also be provided to attract missiles with infra-red homing heads.

Other on-board equipment includes the battery-powered electrical system, the automatic flight control and stabilization units, the command control and tracking aid equipments, as well as a teledata package which provides up to six simultaneous information channels over the tracking aid radio-frequency link. The target vehicle has sufficient reserve space and weight to provide a generous growth potential.

Radioplane RP-76 Target Drone



Powerplant	1 solid-propellant rocket motor with 37 lb thrust
Span	60 in.
Length	116 in.
Height overall	18.2 in.
Fuselage diameter	12 in.
Wing area	7 sq.ft.
Weight equipped	210 lb
Propellant weight	90 lb
Launch weight	300 lb
Maximum speed	Mach 0.94
at	40,000 ft
Service ceiling	over 60,000 ft
Endurance (including glide)	over 20 minutes

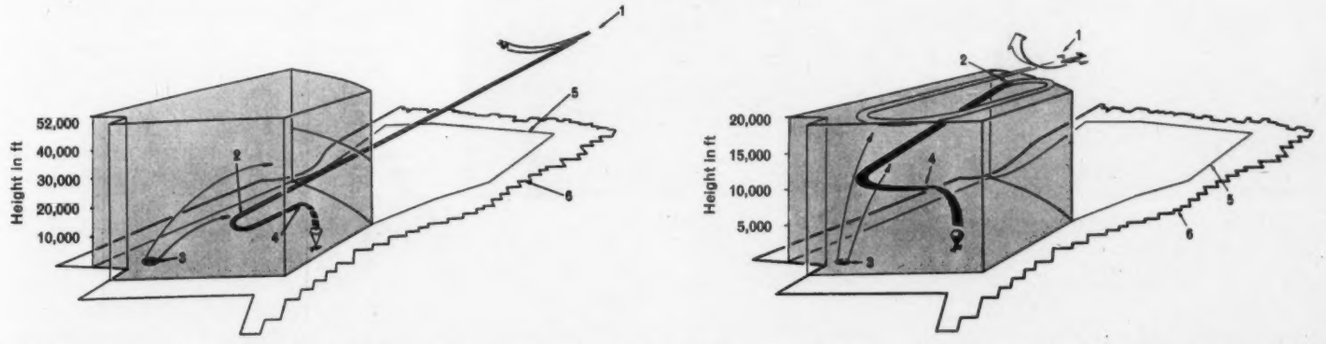


Equipment layout of the RP-76, showing the following (left to right): radar signal amplifiers; tracking, radio guidance and control equipment; rocket motor with two nozzles; recovery device.

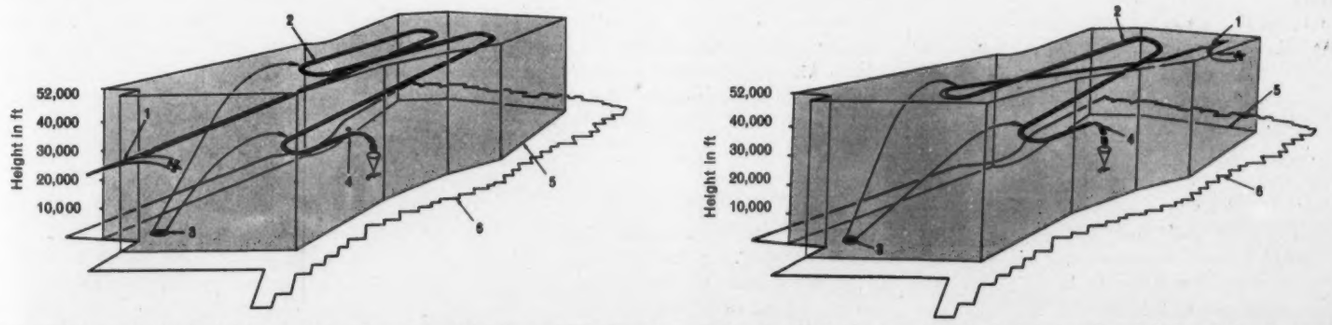
...and ground support equipment

The key element of the ground and air support portion of the target system is the Northrop-designed ground command control and tracking station. It is composed of readily available equipment combined to function for all types of intercept missions, and comprises the slaved antenna assembly, the flight control box, coder, transmitter, preamplifier, master control panel, Sanborn recorders and plotting board. The two channels of the teledata link can be used as a scoring system, if desired. The ground station also furnishes two independent tracking units to provide an operational capacity for flying two target missions simultaneously. The tracking system of the ground station uses radio signals from an on-board transmitter to derive slant range and azimuth angle. The computer converts the slant range and azimuth angle information into coordinates on a standard plotting board for control purposes, and also furnishes information to the firing unit as early warning.

For the ground and air support elements of the target system no complicated system checkouts are required during ground pre-flight activities, and once the target is airborne under the wing of its carrier aircraft, the pre-launch checkout can be accomplished in one minute.



Two mission profiles for RP-76 drones used as targets for Raytheon *Hawk* surface-to-air missiles. 1 – target launch; 2 – burnout; 3 – missile launch site; 4 – target recovery; 5 – limit of danger zone; 6 – McGregor range boundary.



Two mission profiles for RP-76 drones used as targets for *Nike-Ajax* and *Nike-Hercules* surface-to-air missiles. 1 – target launch; 2 – burnout; 3 – missile launch site; 4 – target recovery; 5 – limit of danger zone; 6 – McGregor range boundary.

The U.S. Army's RP-76s are maintained not by military personnel, but by Radioplane technicians. Radioplane has established a maintenance and storage facility at El Paso, Texas, near the McGregor Range, where the targets are received and assembled. Close by, at the El Paso airport, the Division also maintains an air support base for the operation and maintenance of the carrier aircraft, and for the ground check-out of the targets. At this facility, the targets are maintained on a standby basis.

Radioplane Q-4B Target Drone

Powerplant	1 General Electric J85-GE-5 with 3,850 lb thrust
Span	approx. 13 ft
Length	approx. 36 ft
Height overall	approx. 6 ft
Launch weight	approx. 3,300 lb
Maximum speed	Mach 2
Service ceiling	over 70,000 ft
Endurance	over 1 hour

Air-to-air missions

The RP-76 can be released from almost any operational aircraft or trainer equipped with normal launching devices. In most cases, two target drones are used. Flying at a speed of Mach 0.78, the carrier aircraft proceeds to a point between 165 and 170 nautical miles from its ground or sea base. During this phase, it is tracked by ground-based radar. One minute after the target-carrying aircraft arrives at this location, at approximately minus 11 minutes to target launch, the first interceptor aircraft is scrambled, and vectoring begins immediately (frontal attack). At minus nine minutes to target launch, the second interceptor aircraft scramble is initiated; and at minus seven minutes to target launch, scramble three is effected.

An XQ-4 being suspended under the wing of a Boeing B-50 with the aid of a transportable hoist.

At the range perimeter, the target is launched. The carrier turns off, making a 180° turn to prepare for a second approach and launch. After about four seconds free fall, the RP-76 automatically fires its rocket motor, which accelerates it to a speed of Mach 0.85 at about 35,000 ft. The first aircraft to scramble has now made acquisition and lock-on and enters the attack phase immediately. At plus three minutes from target launch the first intercept attack occurs. At plus five minutes after target launch the second intercept is made, and at plus seven minutes after target launch the third intercept aircraft attacks.

Using the same flight plan conditions, four scrambles and attacks can be made from abeam, or three from the rear. The target, being usable in all modes of attack, is readily compatible with the GAR-1 and GAR-3 missiles, and can be adapted for compatibility with the GAR-2, GAR-4 and GAR-8 with only slight configuration changes.

Anti-aircraft missions

A McGregor Range target mission between ARADCOM (Army Air Defense Command) at Fort Bliss and the Radioplane contractor-operated flight service follows a simple procedure. The ARADCOM training evaluation officer notifies the contractor flight service that a given number of missions will be required the next day at a predetermined time. The contractor's personnel at the airport then accomplish a "go" or "no go" checkout of targets and stand by to await the scramble call. Simultaneously, the crews prepare for firing practice, and the range and frequencies are cleared.

The next day, at Fort Bliss, the evaluation officer decides the time for the scramble call. Within twenty minutes after the scramble is called, the carrier and target are on station. Tracking and acquisition are immediately initiated by the ground station, and the missile batteries are given early warning. Immediately following the early warning, the missile firing-site radars being their search to acquire the target. For *Nike-Ajax* or *Nike-Hercules* missions the Luneberg lens is used for both X band and S band augmentation and furnishes radar simulation of the appearance of contemporary bombers.

The target is completely controllable and maneuverable from the ground station. Climbs, dives, climbing and diving turns and 360° turns can be executed. Once the RP-76 is acquired by the missile battery, it is tracked to a predetermined point on the range, at which time the "defending" missile is fired.

After a mission the RP-76 can be recovered by parachute. For this purpose, a small ribbon parachute is first released, followed by a larger parachute; these are normally released by a radio signal, but can also open when control signals cease, when the drone's power supply fails, or when it reaches a certain altitude. The recovered drones are overhauled at the Radioplane maintenance facility and are then ready for the next mission.

Radioplane Q-4 target drone system

Considerably larger and heavier than the RP-76, the new Radioplane Q-4 target drone is suitable for high supersonic missions. It was developed to U.S. Air Force specifications, but could also be used by the other armed services. The drone is compatible with weapon systems employing *Falcon, Sidewinder, Nike, Talos, Hawk, Sparrow, Terrier, Tartar* and *Bomarc* missiles. Through the use of the GC-130A as a carrier, launcher-director aircraft and logistic support aircraft, the Q-4 target drone is capable of performing a mission anywhere in the world at very short notice.

To simplify maintenance of the Q-4, which is powered by a General Electric J85-GE-5 jet engine, the fuselage can be divided into three sections: forward, center and aft. The forward section consists of a fibreglass radome and an electronic equipment section. The center section is composed of an integral fuel cell, landing bag compartments, the main parachute and the payload. The aft section incorporates the aft impact bags, turbojet engine and first and second stage parabrakes.

The radar augmentation system of the Q-4 can be preset to simulate the reflectivity of aircraft as large as the Convair B-58 *Hustler*. In addition to infra-red flares, the Q-4 carries a smoke-puff

A Q-4B target drone under the wing of a Lockheed GC-130A *Hercules*. The Q-4B has been flight tested at the U.S. Air Force test centre at Holloman AFB, New Mexico.

type system which assists in visual acquisition, and a scoring system which records the distance between the drone and an attacking missile in real-time coordinates. The modular principle of component assembly has been employed, enabling equipment items to be rapidly changed for different missions. The ground support equipment includes installations for testing, maintenance and missile guidance. The last mentioned consists of a microwave radio command system developed by Sperry.

Applications

The Q-4 is suitable for a wide variety of overland and overwater missions. It can be used for both high-altitude, high-speed missions and medium-altitude, medium-speed missions. The drone's relatively long endurance enables several guided missile attacks to be carried out during a single flight.

When the current development programme is concluded, the American fighting forces are expected to place orders for a considerable number of Radioplane Q-4 target drones. ←

RPTA Tracking Aid System

The RPTA tracking aid system, produced by Radioplane Division of Northrop Corporation, is used in conjunction with the RP-76 and RP-77 target drones. It consists of a very light transmitter, installed in the missile, a ground station direction finder receiver with antenna, a computer and a position plotting board. The RPTA system works on an audio frequency tone, which is generated at the ground station and modulates the ground command guidance radio transmitter. This audio frequency, which is demodulated aboard the missile, in its turn modulates the RPTA airborne transmitter. The ground station direction finder, which works in conjunction with an integrated automatic tracking system, receives the retransmitted modulated signal. The tone is once again demodulated and its phase compared to that of the signal originally generated, the range of the target being determined from the delay between the two phases. The drone's position and altitude can then be calculated from the measured range and the position of the antenna. Position data are inscribed directly and continuously on the two-pen plotting board.

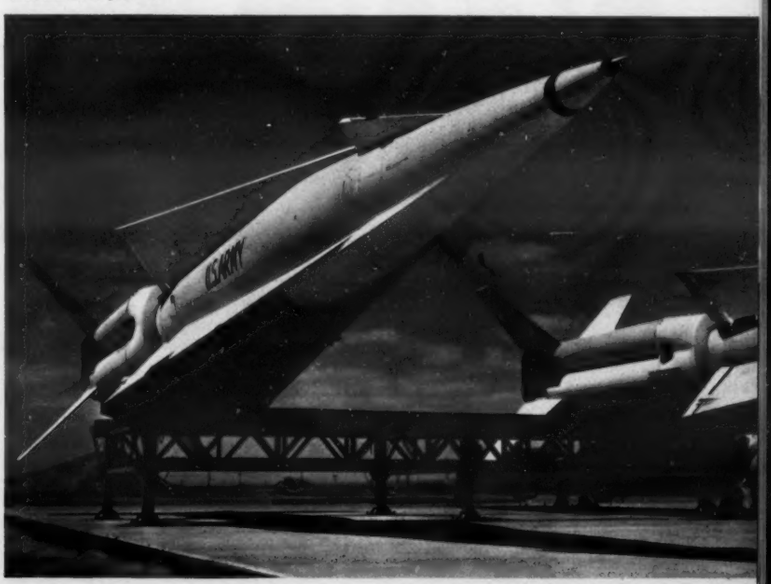
A command control system is not essential for the operation of the RPTA. In cases where this is not available, an audio frequency tone transmitter and a simple airborne receiver-transmitter are employed in place of the command transmitter, coder and decoder.

Technical data

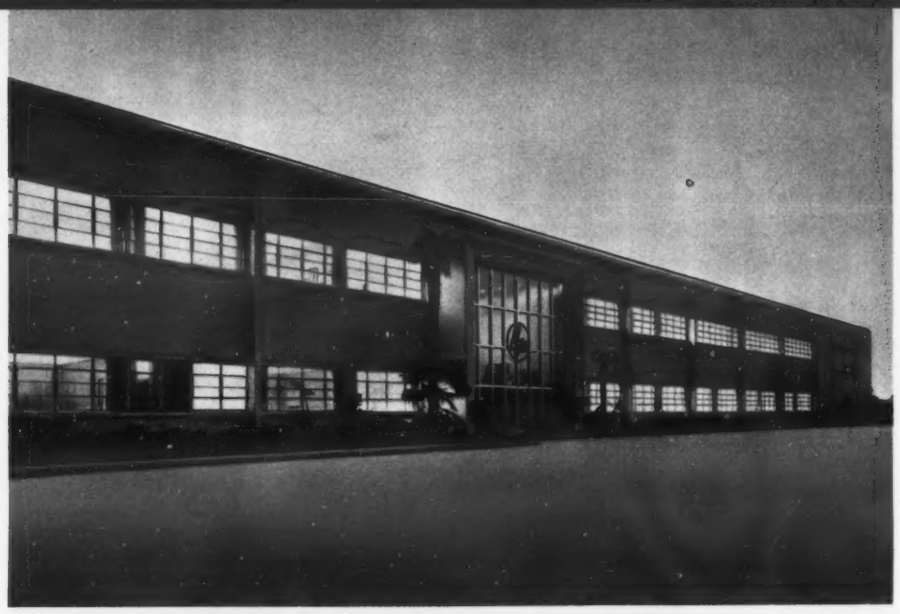
Operational accuracy: azimuth and range ±1,500 ft; altitude ±1,000 ft
Slant range: 100 miles
Angular coverage: azimuth 0—360°; elevation —5° to +90°
Max. slant range tracking rate: 5 miles per second
Max. azimuth and elevation angle tracking rate: 6° per second
Operating frequency: 1,650—1,700 Mc/s
Command transmitter frequency: any
Weight: ground unit 2,000 lb; airborne unit 1.75 lb
Power consumption: ground unit 5,500 watts; airborne unit 30 watts

Three Raytheon *Hawk* anti-aircraft rockets on a mobile launcher. As will be seen from the RP-76's mission profiles on page 357, the drone can be used as a target for the *Hawk* at relatively low altitudes.

The Western Electric/Douglas *Nike-Ajax* and the *Nike-Hercules*, illustrated here, can destroy the drones at higher altitudes. The *Nike-Hercules* can destroy an RP-76 at an altitude of 55,000 ft.



Autonetics — A Division of North American Becomes a Large Concern



Headquarters building of Autonetics, a Division of North American Aviation Inc., Downey, Calif.

"Sales were the third largest in company history, and non-aircraft sales accounted for more than half the total." This is the opening sentence of the 1960 Annual Report of North American Aviation Inc., whose electro-mechanical production activities are grouped under its Autonetics Division at Downey, California. Apart from this, the tendency revealed by the Report does not differ from that which has characterized the American aircraft industry generally over the last ten years.

After the undreamt — of production records achieved by the U.S. aircraft industry in World War II and the second lease of life which it received during the Korean crisis, it was brought home to all concerned that the industry could no longer live exclusively on the aeroplane to which it owed its rise.

It was then, at a time when aeroplane manufacturers were moving heaven and earth to diversify their production programme, that North American laid the foundations of the Autonetics Division, which in a few years was to develop into the major factor of the entire enterprise.

Today indeed the designation "Division" is misleading and certainly no longer does justice to the place of Autonetics within North American. The "Division" we are confronted with is, in fact, a large enterprise in itself, with many ramifications, a large measure of autonomy, a turnover of hundreds of millions of dollars, numerous sub-divisions of its own and several branches in the USA and Europe.

A useful impression of Autonetics' economic potential can be gained by a breakdown of North American's turnover for the year ended September 30th, 1960 (some $965 million) by divisions. In this period, the sales of the two aircraft divisions, Los Angeles and Columbus, amounted to about $261 million and $132 million respectively. The Rocketdyne Division turnover was $176 million, the Missile Division $82 million and the Atomics International Division $49 million. The sales achieved by Autonetics Division in the same period amounted to $265 million.

The figures just quoted speak for themselves and it is hardly surprising to find that during the lost two years the number of employees in Autonetics has trebled (about 23,000 as against 7,000) and floor space has increased by some 50%.

Research Laboratory to Production Line

With a foresight of things to come—and North American has seldom been found wanting in foresight—James H. "Dutch" Kindelberger, Chairman of North American, towards the end of the war called a few scientists, engineers and technicians on his immediate staff together, and informed them of North American's intention to put out feelers in some new fields of research, which had been much talked of during the war and which opened up well-founded prospects for the future. Early in 1946 the Aerophysics Laboratory was born, which in 1948 transferred its activities from the parent plant at Los Angeles to the garden city of Downey.

For some years the Aerophysics Laboratory was concerned exclusively with research and development work on behalf of and for the account of North American, such as automatic pilots, fire control systems and automatic navigation systems. Gradually, development orders from the armed forces came along for an inertial navigator, a missile control system and an automatic landing system for the *Navaho* missile.

Meanwhile, the now considerably expanded research laboratory was redesignated the "ElectromechanicalEngineeringDepartment," and from this Department there emerged at the end of 1955 the Autonetics Division,

John R. Moore, President of Autonetics

Robert T. Jones, Vice President (Foreign Relations)

William F. Hafstrom, Vice President (Marketing)

Rolf D. Cape, Vice President, (European Office, Geneva)

Swedish executives at Autonetics in Downey. Left to right: W.V. Gres, Manufacturing Manager, Autonetics Inertial Navigation; R. Moore, President of Autonetics; Gunnar Ericsson, Managing Director of Atvidabergs Industrier; and Dr. Eric Stemme, Atvidabergs Technical Director. The Swedish visitors signed an international licensing agreement between Atvidabergs and North American.

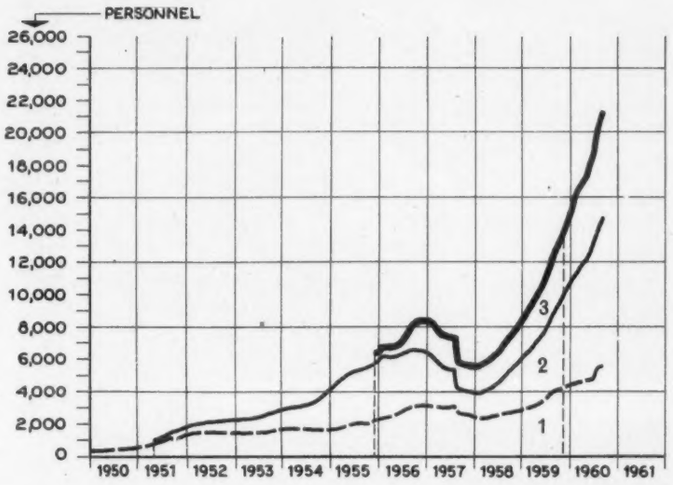
which today possesses, in addition to five production departments, all the administrative and commercial departments appropriate to an independent industrial enterprise. These include long-range planning; marketing (market research and sales); international operations; research and engineering; and reliability and quality control.

The five production departments comprise Inertial Navigation; Computers and Data Systems; Armament and Flight Control; Industrial Products; and the Minuteman System Management Division. It is hard to say which of these individual departments is the most important economically, since no separate departmental balance sheets or reports are published. It is, however, certain that the Computers and Data Systems Department achieves a very considerable turnover; for example a decision has been awaited for some months for a fire control and computer system for the U.S. Army field artillery which, if favourable, is expected to involve an order of 2,000 instruments at $100,000 apiece. The non-military digital computer RECOMP II (Industrial Products Department), which can be either bought outright at $95,000 or rented, is also meeting with a good reception; the equipping of North American's *Hound Dog* air-to-ground missile should be extremely profitable business; nor should the supply of radar fire control systems for the F-104 and F-105 fighter-bombers as well as for the T-39 trainer be underrated. And we have still not mentioned the inertial navigation systems which guide the *Minuteman* on its path, the A3J *Vigilante* naval strike aircraft on its attack and the atomic submarines USS *Nautilus, Skate* and *Sargo* on their routes under the polar icecap.

J. R. Moore, President of Autonetics Division, attributes the stupendous success of his young enterprise largely to "Dutch" Kindelberger and to J. L. Atwood, North American's President, but this is probably no more than dutiful respect for his chiefs, for on closer inspection it does not look as if the management of Autonetics needs lessons from anyone in how to run its business.

In defining the principles of Autonetics business policy, President Moore stated that his organization seeks out little-worked or hitherto overlooked fields which offer outstanding growth and sales potential. If several competitors are already interested in a tender, then Autonetics' practice is to abstain. Furthermore, an iron hand is kept on overheads, and all unprofitable extravagant projects are dropped at once. The rule is that Autonetics builds components itself only when it cannot find a supplier.

These observations are tellingly underlined by Vice President W. F. Hafstrom, head of Marketing in Autonetics, when he says that Autonetics has no off-the-shelf products for defence programmes. Though many computers and inertial guidance systems have broad potential application, each unit is designed and built for a specific system. Hafstrom goes on to point out that "our job is to find out what the Department of Defense wants and provide it" and that, continually operating on the edge of the state of the art, Autonetics' philosophy is "if you know how to build it, it's obsolete."



Graph showing growth in the number of staff employed in the three main sides of Autonetics' activities: 1. Engineering, 2. Manufacturing, 3. General supporting activities (including purchasing, sales and customer relations). Up to the end of 1955, when Autonetics Division was formed as such, the figures relate to personnel employed on equivalent activities in the parent company.

The Production Programme

Let us now turn to the individual products which brought Autonetics to the forefront of electromechanics in the USA.

Inertial Systems

Pride of place in Autonetics' programme of work belongs to inertial navigation and control systems. As early as 1950, the first automatic inertial navigation system was installed in a DC-3 and subjected to comprehensive flight testing. Later versions served for control of the supersonic North American X-10 unmanned test vehicle and of the now abandoned *Navaho* missile. Further development work led to improved inertial systems, which are today in operation. For example, all *Polaris* submarines use Autonetics' N7A inertial autonavigator, and the voyage under the polar icecap by USS *Nautilus, Skate* and *Sargo* was carried out by means of the N6 inertial navigator. Both the inertial control systems in the *Hound Dog* GAM-77 air-to-ground missile and the U.S.Navy's A3J *Vigilante* produced by North American are by Autonetics. A stellar inertial navigation system for the B-70 *Valkyrie* strategic bomber is under development.

In the production of inertial navigation and control systems, Autonetics lays the greatest stress on reliability, precision and compactness. In some cases the individual units are produced in shops with air pressure slightly above normal to prevent the entry of dust-laden air. Temperature and air humidity are also regulated within very narrow limits. The research and development engineers have the most modern testing equipment and computers at their disposal, and the machine tools, partly designed and developed by Autonetics itself, work with almost unimaginable precision. For example, according to factory information, the tolerance in the production of precision gyros and accelerometers for inertial guidance system is less than one thousandth of a millimetre.

Precision gyros of this type are also the heart of Autonetics baseline equipment known as ABLE. This transportable direction-finding equipment determines true north rapidly and accurately in all weathers and by day or night. By means of a theodolite scale, missile launchers, mobile radars or other angle-calibrated equipment can then be immediately aligned.

Computers

Two further departments of Autonetics deal with the development and production of electronic computers and data processing systems for military purposes, as well as computer installations for non-military purposes and automation systems for industry. For example, Autonetics offers RECOMP (REliable COMPuter) II, which is a fully transistorized portable general purpose

The gyro-stabilized platform, part of the ship's inertial navigation system (SINS), under inspection in the navigation compartment of USS *Theodore Roosevelt*.

Various Autonetics systems, including the SINS inertial navigator illustrated here, are in use on board the USS *Nautilus*, famous for its polar voyage.

Autonetics produced this "quick thinking" field artillery digital automatic computer (FADAC) for the U.S.Army, which enables the gunners to engage new targets at high speed.

By means of this pilot display projector, a luminous pattern projected on to the windscreen is used to transmit navigational and directional information to the pilot, for instance when visibility is poor.

digital computer, which needs no more current than a toaster. This computer can be used for mathematical calculations, analyses, data processing, production control, and even navigational purposes. The use of subminiaturized magnetic disk type stores enables the computer to be kept small and compact. A new model, RECOMP III, is now coming on to the market.

Autonetics has also developed a series of computers for military purposes, in the first place the VERDAN digital computer, which is incorporated in various systems. As part of the inertial navigation system of the *Hound Dog* air-to-ground missile, this computer combines the advantages of a digital differential analyzer, capable of the real time computation required for missile guidance, with those of a general purpose computer for periodic self-tests and fault diagnosis. The same computer is installed in the *Polaris* submarine's N.7A inertial navigator and the navigation and control system of North American's A3J *Vigilante*.

A special military application for digital computers is found in Autonetics' field artillery digital automatic computer, FADAC. This equipment evaluates input data concerning direction of target, distance, wind, etc. and produces accurate firing information quickly under extremes of temperature, dust and humidity. The equipment is transistorized, small and robust, and can, in an emergency, even provide data for several different batteries. FADAC is a general purpose computer, and different control sections tailored to specific needs can be easily incorporated. The same department of Autonetics is responsible for the basic automatic checkout equipment BACE, which, by pre-programming the incorporated digital computer, can carry out tests of complete electronic and electromechanical systems.

Finally, mention should be made under this heading of the North American Data Airborne Recorder NADAR, a magnetic tape recorder which captures both flight measurements and the human voice. At the end of the flight, the magnetic tape can be immediately played back on the ground playback unit. Later models in the form of digital equipment show the whole course of a mission, from lock-on to escape manœuvre, and immediately record all important data concerning the dynamic interaction of pilot, airframe and weapon. The equipment can be used to test and evaluate fire control systems, in test flights and special investigations during test flights, as well as for pilot training and many other purposes.

Armament Control Systems

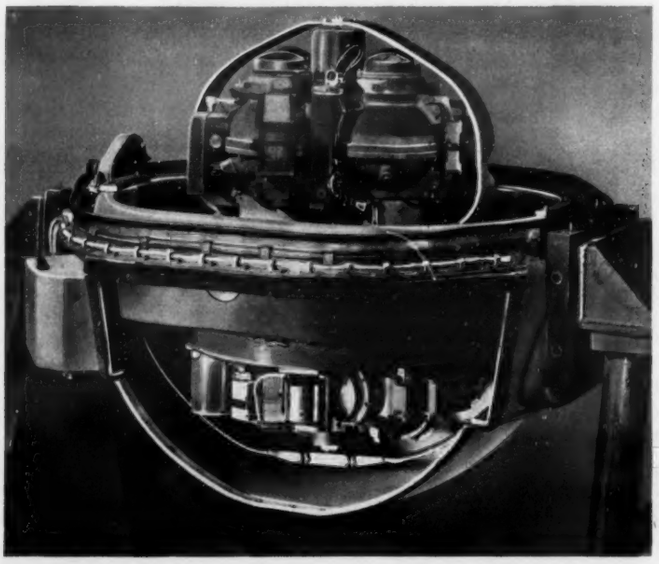
Autonetics has years of experience in the development and production of weapon control systems. At one time, the MG-4 weapon control system was in production in considerable quantities for the F-86K (armament: 20 mm cannon) but this has now come to an end. On the other hand, the North American Search and Ranging Radar NASARR (for the Republic F-105) and the Super-NASARR (for the Lockheed F-104) are in current production. The Super-NASARR is intended for the F-104 in the Canadian, Japanese, German, Dutch, Italian and Belgian air forces and is to be produced in Europe under licence in the countries concerned. Both models give fighter bombers all-weather capability and offer the pilot various modes of operation, such as radar ground mapping, terrain avoidance, air search and tracking, and ranging of ground targets for various aircraft weapons. The equipment is light, compact, and equally suitable for low-level and high-level missions.

The Minuteman Guidance System

Autonetics is responsible for the entire guidance system of the *Minuteman*, and this project occupies a major place in its programme. Both the missile's inertial guidance system and the fully transistorized digital computer it carries, are produced by Autonetics. The latter not only works as part of the guidance system in flight but also assists in the comprehensive pre-launch operational testing which has to be carried out at high speed. The ground units of the *Minuteman* system consist of the guidance and control computer (for input of all data into the rocket, transformation of data between missile and ground computer, and monitoring of the missile computer's output during operational testing), a missile targeting and control console, a digital printer, and a tape perforator console.

Other Products

It is, of course, not possible to deal in this short survey with all the equipment and systems covered by Autonetics' programme. Besides, certain developments which might be successful in the civil sector have not yet reached the production stage. For instance, air traffic circles are showing considerable interest in the automatic blind landing system, which would be specially suitable for jet aircraft, particularly as it has already made it possible since 1955, for Mach 2 aircraft (X-10), to land automatically. Air traffic operators also seem to welcome the pilot display projector which uses a luminous pattern projected on the



The American atomic submarines USS *Nautilus*, *Skate*, and *Sargo* were guided under the North Polar icecap by this N6 inertial navigator.

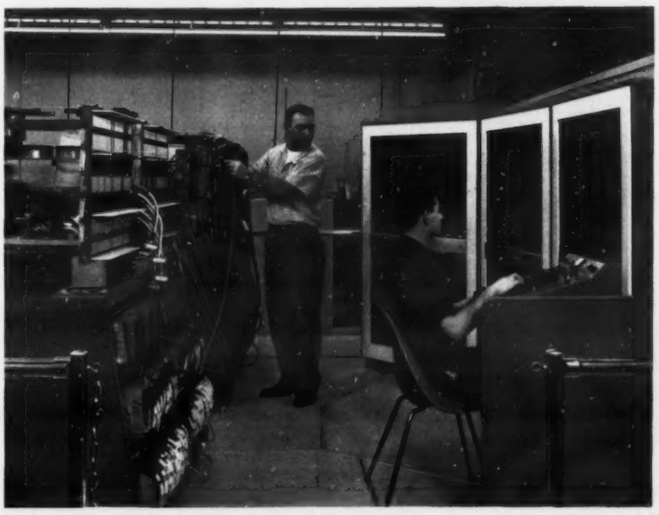
Precision components for inertial navigation, as well as other instrument and electromechanical equipment made by Autonetics, demand ultra-clean production conditions. Dust count is kept to one five-hundredth of normal, temperature is controlled within plus or minus 1°F and humidity is regulated with 2 percent constancy.

windscreen to transmit navigational and directional information to the pilot, for instance when visibility is poor.

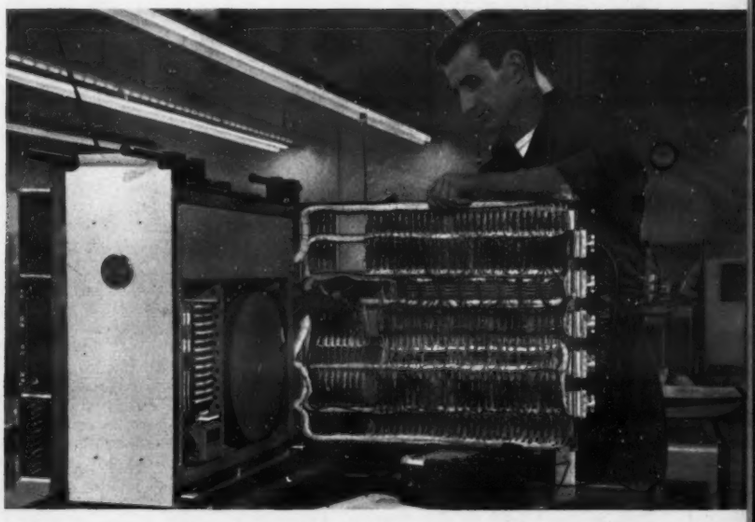
Other interesting items produced by Autonetics are automatic numerical controls for machine tools, automatic process control equipment, and automatic test equipment for industrial use; programmer-comparators for automatically sequencing tests on complex systems; multi-channel magnetic tape recorders; high speed photo-electric tape readers; card programmers; and printers.

Strong Preponderance of Military Orders

Like the rest of the aviation industry, North American Aviation, Inc., at present depends essentially on one client, the U.S. Government, whose orders accounted last year for over 95% of the turnover of Autonetics' five production departments. Only the Industrial Products Division is dedicated to non-military production, and its share of Autonetics sales currently amounts to some 2%. Now the Government, whilst a good payer, is not



This neon indicator flashing test equipment (NIFTE) by Autonetics is for continuous checking of certain computer components.



The "Recomp", a transistorized computer produced by Autonetics Industrial Products.

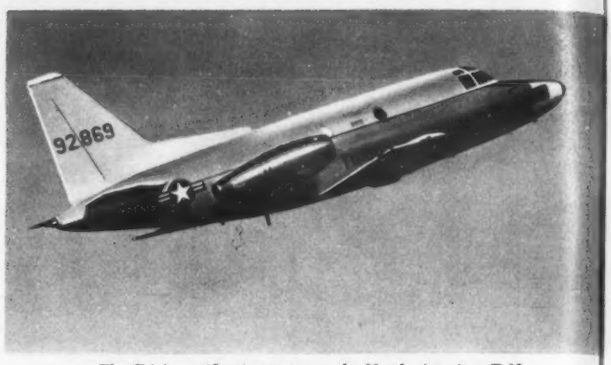
The production line at Autonetics for the versatile VERDAN digital computer, which is an integral part of the *Hound Dog* air-to-ground missile's inertial navigation system and of the *Polaris* submarines' N7A inertial system.

always an easy customer, and it is certainly ill-advised to put all the eggs in one basket. President Moore put it this way: "We are not trying to get out of the defense business as much as we are trying to get into non-defense work." Anyway, he declares his intention to raise the share of the Industrial Products Division in the near future to 10% of the total turnover and to reach 40% on a longer term basis.

Moreover, looking further ahead, Autonetics will continue to develop more in the field of electromechanics than of electronics. President Moore considers that the next few years will not see a further expansion in the number of employees, but the engineering staff will in all circumstances be maintained.

To sum up, the company is, according to President Moore, still in a "research and development" phase of its activities and seeking to broaden its base of operations and achieve a permanent industrial stability. ◆◆

What's in the Air?



The FAA certification tests on the North American T-39 multi-purpose and training aircraft, powered by two Pratt & Whitney J60-P-3 engines (each 3,000 lb thrust), have begun. This programme will finish by the end of April, and official certification should follow in May. The USAF has already ordered 94 aircraft of this type. A civil version is also available.

AIR TRANSPORTATION

IATA has protested to the British Ministry of Aviation against the 33⅓ percent increased landing fees due to be introduced on April 1st. The new increase will mean that U.K. airport charges will have been raised by between 125 and 250 percent (depending on weight) over the last four years. London and Prestwick will be the most expensive airports in the world, and the additional cost to airlines will be as much as £2 million in the first twelve months' operations.

The present Boeing 707 or Douglas DC-8 landing fee will go up from £181 to £240, and this compares with the maximum night rate of £50 at Amsterdam, £117 Brussels, £74 Copenhagen and £115 Paris. The sum of all possible charges at New York is £122.

A comparison of landing fees and traffic volume at five major airports shows the following figures:

	Passengers handled in 1959	Total Aircraft Movements in 1960	DC-8/707 landing fees (in £ sterling)
Chicago-Midway	9,658,000	431,600	22
New York-Idlewild	6,994,000	239,836	122
Los Angeles	5,893,000	316,068	5
San Francisco	4,111,000	235,229	26
London	4,097,000	129,641	240

Yugoslavia has agreed Austrian proposals for a new 185-mile Vienna-Venice airway via Klagenfurt, Ilirska Bistrica and the northern Adriatic, to replace the present 450-mile dogleg route via Munich. New beacons are being installed near Ilirska Bistrica and Venice. ICAO acceptance is expected for service this summer.

Economy class fares have been introduced between Europe and South America this month, following IATA carriers' agreement (Aerolíneas Argentinas, Air France, Alitalia, BOAC, Iberia, KLM, Lufthansa, Panair do Brasil, SAS, Swissair and TAP). Specimen jet rates from Paris are: Rio $410 (against $540); Buenos Aires $463 ($570); Santiago $508 ($617). Piston-engine rates are $30–40 lower.

Air France will introduce daily direct *Caravelle* service Paris–Manchester on June 1st. Frequency will be cut to four flights a week (Monday, Wednesday, Friday and Saturday) from September 21st. Departures Paris-Orly 10.00 hours and from Manchester 12.35 hours. Flight time 1 hour 25 minutes.

Irish International Airlines' Boeing 720 frequency to and from New York will be stepped up from three to four flights a week effective April 29th, and to daily service from May 28th. Boston will be included five times a week at the peak summer period.

Netherlands Transport Ministry has approved the full development programme for Amsterdam-Schiphol Airport. Allocations for 1961 total Fl.18 million ($4,7 m.) and the State will guarantee further loans in 1962 and 1963. Construction will start this spring on a new runway 09/27, and 01R/19L will be extended to 10,000 ft. A fourth runway (01L/19R, 10,000 ft) will be built in 1964/66. The Amsterdam-Hague motor road will be rerouted to permit construction of new central terminal area.

The U.S. Federal Aviation Agency is organizing an international symposium on aviation research and development for a mutual exchange of technical progress in the aeronautical field. A five-day session is planned for April 10th-14th at Atlantic City, N. J. and acceptances have already been received from Canada, Switzerland, U.K., United Arab Republic, Uruguay and West Germany. Nine other nations have indicated their intention to send representatives and a further 13 are interested. This will be the first in a series of annual meetings to be sponsored by FAA.

Delta Air Lines, one of the twelve U.S. trunk carriers, has announced that it will not use Washington's new Dulles International Airport (28 miles to south-west) but will continue to use Baltimore Friendship International Airport (35 miles east) for its jet flights. Delta cites potential business from Baltimore's one million population as the deciding factor and is the first carrier to make a definite announcement concerning use of Dulles International.

The medium-range Convair 990, fitted with four General Electric CJ-805-23X aft-fan engines of 16,000 lb thrust, began flight testing on January 24th. The aircraft is shown here on its maiden flight, shortly after becoming airborne. The intercontinental version of this model (already ordered by SAS and Swissair) is known as the Convair Coronado. *The Convair 990 will have an all-up weight of 239,200 lb, span 120 ft, length 139.5 ft, wing area 2,250 sq.ft.* 3

Riddle Airlines will have all seven Armstrong-Whitworth *Argosies* and seven Douglas DC-7Fs in service by the end of this month.

Ansett Transport Industries Ltd. has taken over the complete shareholding in Mandated Airlines (New Guinea) with a wide network of routes in Papua-New Guinea, mainly concerned with freighting and the transport of native labour. The purchase price of £A 950,000 is partly covered by an issue of ATI shares, but no details have been given. The deal includes considerable property as well as the carrier's operating licences and a fleet of nine DC-3s, six lighter aircraft *(Norsemen, Junkers, Rapides)* and two Piaggio 166s which were due for delivery last month. Mandated is the sixth airline subsidiary acquired by Ansett in the last three years. Ansett-ANA will be in competition with Trans-Australia Airlines throughout the developing Papua-New Guinea territories where TAA has taken over the well-developed network formerly operated by Qantas.

INDUSTRY

European F-104G airframe production is now allocated: Arge Süd (Dornier, Heinkel, Messerschmitt and Siebel) 210, Arge Nord (Fokker, Aviolanda, Hamburger and Weser Flugzeugbau) 350; West Group (SABCA, Avions Fairey) 195; Fiat 194. Total 949.

Main engine contractors are: Germany - BMW; Belgium - F.N.; Italy - Fiat. Each company will be responsible for final assembly and for component groups for the other two.

Electronics equipment will be supplied by various companies, including Telefunken (NASARR), Standard Elektrik Lorenz (TACAN), AEG (optics), Eltro (infra-red), Teldix (PHI), Interaero (flight data computer), Litton (inertial navigator) and Honeywell (autopilot) in Germany. Philips (NASARR), Van der Heem (radio), Onde Delf (infra-red), and Monroe (inertial navigation) in the Netherlands. Bell Telephone Manufacturing (PHI, flight data, inertial navigation), ACEC (autopilot), OIP (optics), and MBLE (NASARR) in Belgium.

Stanford Research Institute is making a six-month study of the commercial potential of hydrofoil vessels under a $60,000 U.S. Maritime Administration contract. Trade routes for "first generation" vessels will be assessed on estimated speeds of 60–70 knots, 500–1,000 miles range and gross weight about 500 tons. An experimental 104 ft, 80 ton hydrofoil craft now being built by Grumman should be ready for testing by mid-1961.

France's Space Research Committee (President Professor Auger) has approved a NF 130 million ($26m.) five-year space research programme with funds allocated under the Government's scientific research programme law. A working programme for the first year has been agreed with funding totalling NF 42 million ($8,4 m.), with an additional NF 16,5 million ($3,3 m.) in obligatory authority for the current year. The five-year programme covers an average 50 high-altitude research launchings a year, with some 20 launchings planned for 1961. Included are the five *Véronique* research rockets under the 1960 programme, and a dozen others including the *Super Véronique* and the new *Bélier* and *Centaure* solid-propellant rockets now under development.

A major study centre is planned for the French Kerguelen Islands in the southern Indian Ocean. Other nations are to be invited to collaborate in research work at this centre, largely devoted to study of the earth's magnetic field and radiation belts.

Hughes Aircraft's design for the *Surveyor* lunar soft-landing vehicle won the NASA competition against North American, Space Technology Laboratories and McDonnell Aircraft submissions. NASA is negotiating with Hughes to build a total of seven *Surveyor* vehicles for the 1963–66 period. The project will aggregate over $50 million.

Bendix Corporation has received a $26 million U.S. Navy contract for continued development and evaluation of the *Eagle* air-to-air missile system.

Victa Consolidated Industries' Aviation Division is sub-contracting work on the Victa (Millicer) *Air Tourer* sports and touring aircraft to speed production and meet Australian Aeroclub requirements in competition with the French Morane-Saulnier *Rallye*. The 95 h.p. Continental-powered modification of the prototype has passed its C of A, and the first all-metal production model is scheduled for delivery in June this year. Victa has letters of intent covering more than 30 aircraft.

Pilatus Aircraft Works of Stans (Switzerland) has booked an order for a *Porter* light utility transport for KLM, Royal Dutch Airlines. The aircraft is to be modified for aerial mapping by KLM's Aerial Survey Division (KLM-Aerocarto NV). Three *Porters* were flown to Nepal last month, two purchased by the Nepalese Government and the third made available by the International Red Cross.

Morane-Saulnier is quoting delivery periods of about twelve months on new orders for the 880 *Rallye* and 885 *Super Rallye*. At the end of January, the company had booked 166 firm orders, 85 for export to 17 foreign countries.

Canadair is making a concerted effort to get new orders for the CL-44 four-turboprop swing-tail freighter, following the collapse of the projected exchange deal with the United States against F-101 *Voodoos*. The last of the 17 aircraft on order will come off the production line in August, and the company will have to have new orders booked by April or May this year if the line is to be kept going.

Canadair's CF-104 assembly line is expected to be in full swing by mid-March, somewhat behind the provisional schedule given by Minister of Defence Production O'Hurley. Last year the Minister said that aircraft should be coming off the assembly line by the end of February this year.

Decca Navigator is supplying Mark 10 receivers and flight logs for the six Handley Page *Dart Heralds* on order for Jersey Airlines, the British Channel Islands scheduled operator.

MILITARY AFFAIRS

First Northrop T-38 Talon deliveries to USAF Air Training Command at Randolph Field are expected in April. The USAF training programme for the next decade eliminates the Beech T-34 *Mentor* and the North American F-100 *Super Sabre* and will utilize the Cessna T-37 and the supersonic T-38 *Talon* jet trainers. Training time will be cut by some 30 percent to 262 hours, covering 132 hours on the T-37 and 130 hours on the T-38.

The Spanish Air Ministry has purchased ten North American T-6 *Texans* in the United States for use by the Air Force Basic Pilot Training School. Price and supplier are not quoted.

First USAF F-105D fighter-bomber units will arrive in Europe this spring, replacing F-100s. The first aircraft will be assigned to the 36th Tactical Fighter Wing based at Bitburg in Western Germany. Depending on the mission, the F-105D *Thunderchief* can carry atomic or hydrogen bombs, *Sidewinder* air-to-air missiles or *Bullpup* air-to-ground missiles, or high-explosive rockets and napalm bombs. The T-105 has been in service with TAC in the United States since late 1958. Three squadrons are based at Seymour Johnson AFB (Goldsboro, S.C.) and one at Eglin AFB (Florida). The 4520th Combat Crew Training Wing at Nellis AFB (Las Vegas, Nevada) is also equipped with the F-105.

Air Chief Marshal Lord Bandon will succeed Air Chief Marshal Sir Harry Broadhurst as Commander of Allied Air Forces Central Europe on March 1st. Sir Harry Broadhurst is retiring from the RAF at his own request and will be Managing Director of A.V. Roe & Co.

Chance Vought's F8U-2N all-weather Crusader *naval fighter with the Pratt & Whitney J57-P-20 jet engine (thrust 18,000 lb), on which carrier operational trials have recently been completed. The trials were carried out on board the aircraft carriers* Forrestal *and* Midway.

Allied Air Forces Central Europe is headquartered at Fontainebleau and controls the Second Allied Tactical Air Force (Belgian, Netherlands, U.K., and West German units) and the Fourth Allied Tactical Air Force (Canadian, French, USA and West German units).

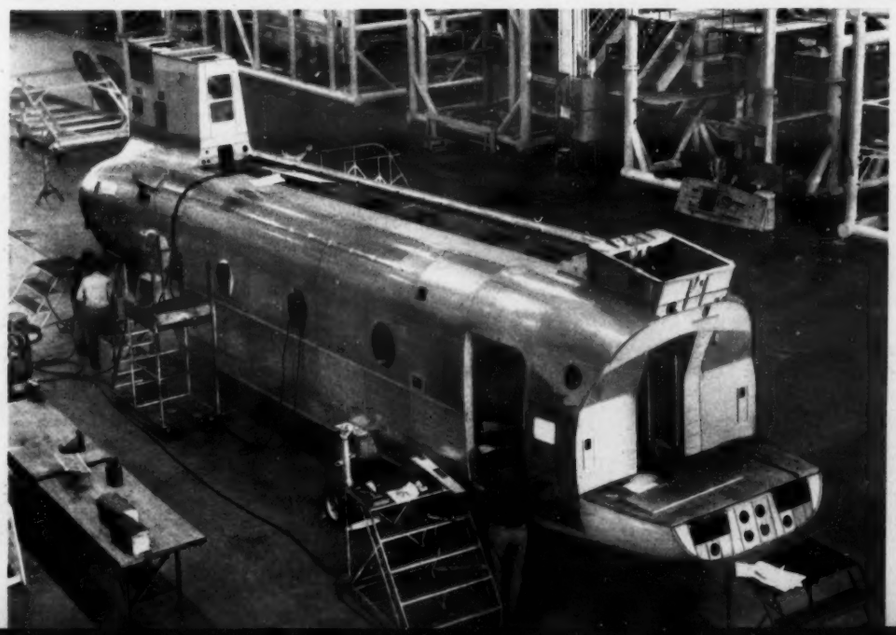
The First Minuteman ICBM railroad car has been rolled out at ACF Industries' American Car & Foundry Division, and has gone to Boeing's Seattle plant for interior fitting. Length over couplings 88 ft; width 10 ft 2 in; height 15 ft 1 in. The car has two 6-wheel bogies and hydraulic shock absorption is used for maximum protection against end shock. Twelve jack pads lift the car from the track to provide a stable platform.

Ultra Electronics Ltd. has negotiated a contract with the Argentine Aeronautical Mission to supply SARAH, Search and Rescue and Homing equipment. Three airborne transmitter/receivers with search aerials will be supplied for installation in Beaver aircraft, together

The Czechoslovak HC-3 three- to five-seat helicopter, designed by Slechta, of which three versions are at present being flight tested. The HC-3 is powered by a M.108H piston engine of 240 h.p. Top speed at sea level is about 90 knots, rate of climb 980 ft/min, hovering ceiling 6,560 ft within ground effect, service ceiling 13,780 ft and range 170 n.m.

The Bell HUL-1M turbine-powered helicopter fitted with the Allison T-63-250-C2 gas turbine. This model, a turbine development of the HUL-1/Bell 47J, is at present being flight tested.

The fuselage of the first Boeing-Vertol YHC-1B Chinook *in final assembly at the Vertol facility in Morton, Pa. Two 2,200 h.p. Lycoming T55 shaft turbines power this helicopter intended for the U.S. Army, which has already ordered ten for operational trials. The first YHC-1B is due for completion early this year.*



In May the Canadian General Electric Company Ltd. will start testing the 2,700 h.p. T64-4 turboprop in a de Havilland Caribou. *The picture gives a comparison of size between the T64-4 and the 1,450 h.p. Pratt & Whitney R-2000 piston engine, which is the standard powerplant for the* Caribou. *The T64-4 has been under development since 1957 and has so far completed over 4,000 hours of static tests.*

with a quantity of beacons. The contract extends SARAH coverage to the south-west Atlantic, and with 25 countries now using the equipment the SARAH chain virtually encircles the world.

The Swiss Cabinet will submit a requisition for the purchase of Dassault *Mirage III* strike aircraft to the Upper and Lower Houses in June. Federal Councillor Chaudet has said that the first batch of 100 *Mirage IIICs* will be fitted with the SNECMA *Atar 9* engine, but further development of the Rolls-Royce RB.146 will be watched with interest. The second batch of *Mirage IIICs* for the Swiss Air Force may be fitted with the Rolls-Royce powerplant.

The all-metal two-seat MFI Junior *built by AB Malmö Flygindustri. This aircraft will go into quantity production at a cost of not more than Sw.Cr. 30,000.*

The Beech SFERMA PD.146 Turbo Travel Air *experimentally powered by Turboméca* Astazou *turboprops (each 440 h.p. take-off rating) and Ratier-Figeac variable-pitch propellers. Flight tests on this aircraft to date show cruising speed as about 260 knots, sea level rate of climb 3,150 ft/min and take-off distance 500 ft over a 50 ft screen,*

AIRCRAFT AND POWERPLANT

The Fiat works at Caselle, near Turin, began flight tests on the Fiat 7002 turbine-powered helicopter on January 26th. The first flight lasted about 30 minutes and was satisfactory. The Fiat 7002, equipped with a Fiat 4700.000 turbo-generator of about 550 h.p., has a two-blade main rotor and a small anti-torque tail rotor on a short boom. The cabin accommodates 5 passengers, and there is room for a two-man crew (or pilot and sixth passenger). Data so far available are: diameter of main rotor 39.4 ft; length 20 ft; normal all-up weight 3,090 lb; design maximum sea level speed 92 knots; sea level cruising speed 73 knots; range approximately 160 n.m. Both the airframe and the engine for the helicopter were built by Fiat under the MWDP.

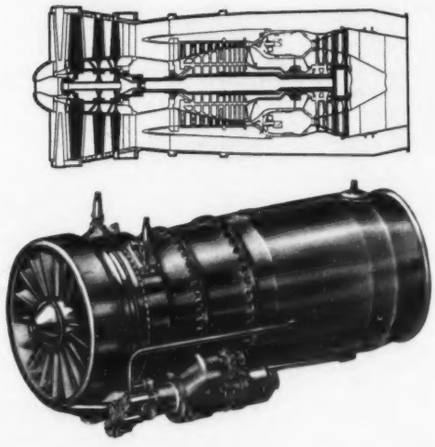
Costruzioni Aeronautiche Giovanni Agusta, Cascina Costa, Gallarate, has received certification from the competent authorities in the USA, Great Britain and Italy for the Agusta-Bell 204B helicopter, which it is constructing under licence in Italy. Agusta has this helicopter in large-scale production for the European market. The 204B is powered by a de Havilland *Gnome* shaft turbine.

Max Holste has completed factory tests preparatory to type certification of the *Super Broussard* short-range and feeder aircraft, and Nord-Aviation will have the major share in its production. Flight tests yielded the following data: The *Super Broussard,* powered by two 1,000 h.p. Turboméca *Bastan* propeller turbines with Ratier-Figeac propellers, attains maximum speeds in level flight of over 215 knots; the rate of climb is 1,770 ft/min at an all-up weight of 21,160 lb. The flight tests included measurements of stalling speed with different loads and varying degrees of flap deflection. The results exceeded the manufacturer's specifications. Average stalling speeds were low, namely 61 knots at 20,500 lb all-up weight and 45° flap deflection (landing configuration). Similar tests carried out in the cruising configuration (undercarriage and flaps fully retracted) showed a stalling speed 20 percent higher. Type certification tests on the *Super Broussard* will be made in the near future, and flight testing of the first production model is set for mid-1961.

Test results on the experimental STOL Breguet 940 will enable important simplifications to be made in the construction of the Breguet 941 and 942 production models. The relatively complicated transmission system will be modified, with resultant economies, and a single reduction gearbox will replace the three reduction gears of each engine in the 940.

A three-seat Jodel Ambassadeur, with a 105 h.p. Potez 4 E 20 piston engine, has been completed by Etablissements Robin-Centre Est Aéronautique and is being flight tested. The choice of the new Potez 4 E 20 for this *Ambassadeur* is due to the intention to install it widely in future three-seat aircraft of French design.

AB Malmö Flygindustri has demonstrated a new all-metal two-seat model, the MFI *Junior,* at Malmö Bulltofta Airport; the prototype of this was originally designed and built by Björn Andreasson as a private venture in the USA under the designation BA-7. Andreasson has since taken charge of Malmö Flygindustri's Aircraft Construction Department, and it is understood that the MFI *Junior* will now go into quantity production in Sweden. The price is expected not to exceed Sw.Cr. 30,000 ($5,800). The *Junior,* fitted with tricycle landing gear and a 75 h.p. Continental A.75 engine, has the following main characteristics and performance figures: span 23.6 ft; length 18.4 ft; empty weight 595 lb; all-up weight 1,190 lb; top speed 124 knots; rate of climb 980 ft/min; range about 540 n.m.; take-off and landing run about 330 ft. Malmö Flygindustri is also working on a four-seat version of the MFI *Junior.*



Drawing and sectional diagram of the new Bristol Siddeley BS.75 front-fan engine which will be installed in the short- to medium-range BAC (Hunting) 107 and the Avro 771. The BS.75 has a high by-pass ratio (1.75 : 1) and is in the 7,000 to 8,000 lb thrust class.

A Westland (Saunders Roe) Scout turbine-powered helicopter has now completed tropical trials in Aden in addition to the cold-weather test programme (temperatures down to —35 °C) at Vickers Armstrongs' Weybridge test facilities, which included simulated snowstorms and very high wind speeds. Full servicing was carried out by the Central Servicing Development Establishment of Dereham, Norfolk, England to test the helicopter's maintainability under extreme weather conditions.

"Specifications for a Business Air Transport," published by North American, includes details of an adaptation of the multi-purpose T-39 (in production for the USAF) as an executive aircraft. The FAA certification programme for the T-39 began a few weeks ago, and type certification will probably be granted in May. The civil version of the T-39, known as *Sabreliner,* will include a luxury cabin for six passengers, and a nine-passenger version will also be available if desired. Structurally, there will be no marked difference between the military and civil versions. Two Pratt & Whitney JT12A-6 jets, each of 3,000 lb thrust, will power the *Sabreliner,* which will have a maximum take-off weight of 17,760 lb like the military version. Maximum cruising speed is given as about 450 knots, stalling speed about 82 knots, service ceiling 45,000 ft and single engine ceiling 21,500 ft at an all-up weight of 14,200 lb. ←→

BRITISH AIRCRAFT CORPORATION

Incorporating the Aircraft and Guided Weapons interests of —

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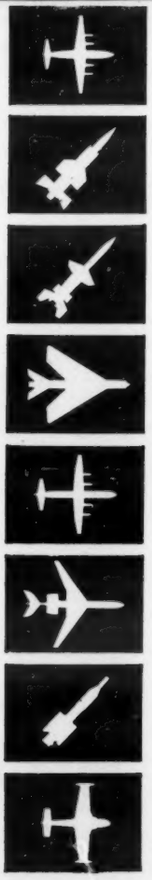

VISCOUNT
VANGUARD
VC 10
BAC 107
SUPERSONIC AIRLINER PROJECT
T-188
CANBERRA
LIGHTNING
TSR-2
JET PROVOST
BLOODHOUND
THUNDERBIRD
VIGILANT
BLUE WATER

BRITISH AIRCRAFT CORPORATION

ONE HUNDRED PALL MALL LONDON SW1 ENGLAND

YGA BAC31

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SECOND GENERATION J

VC10 projecting the C

...and built by **BRITISH A**

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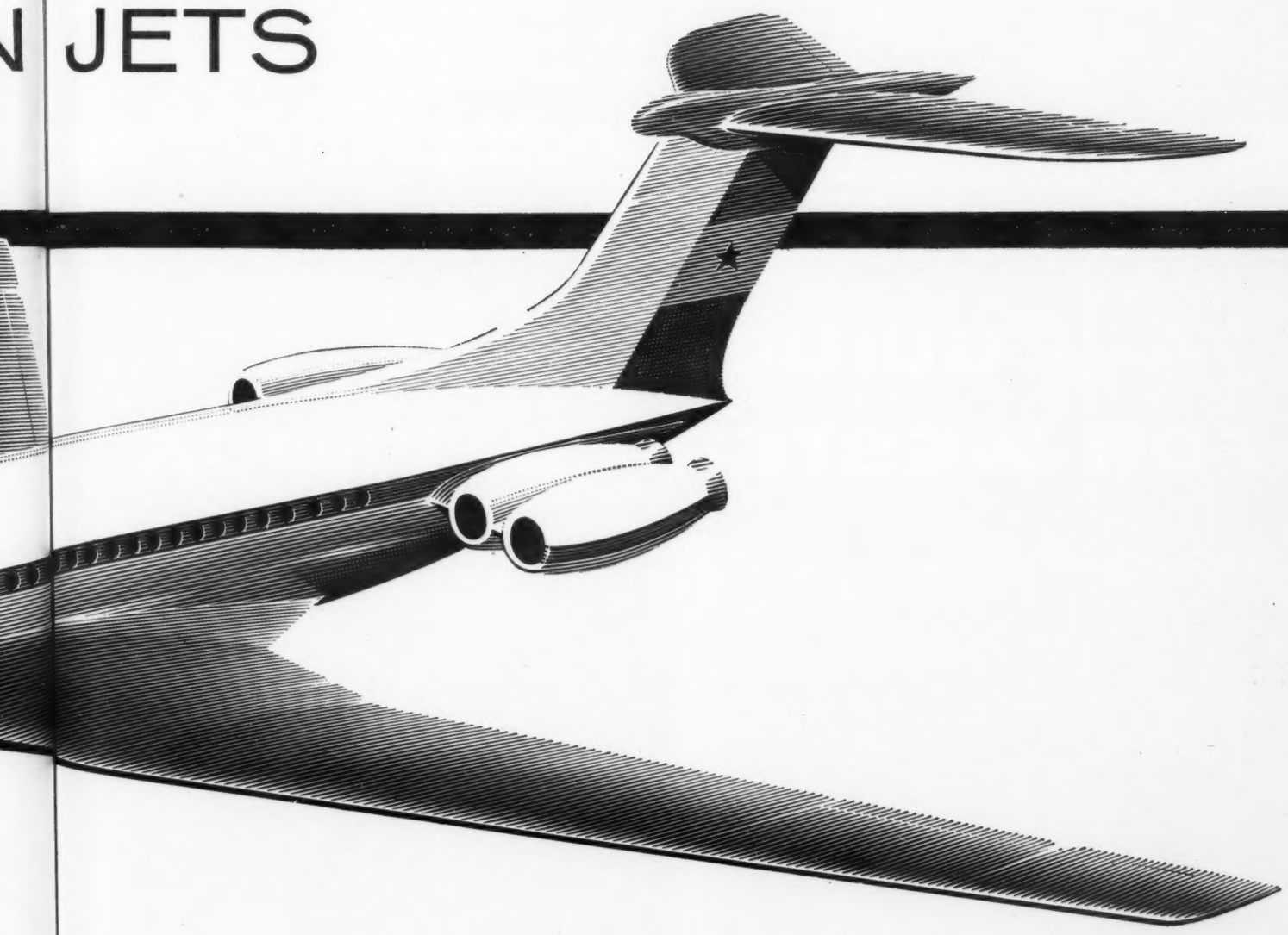
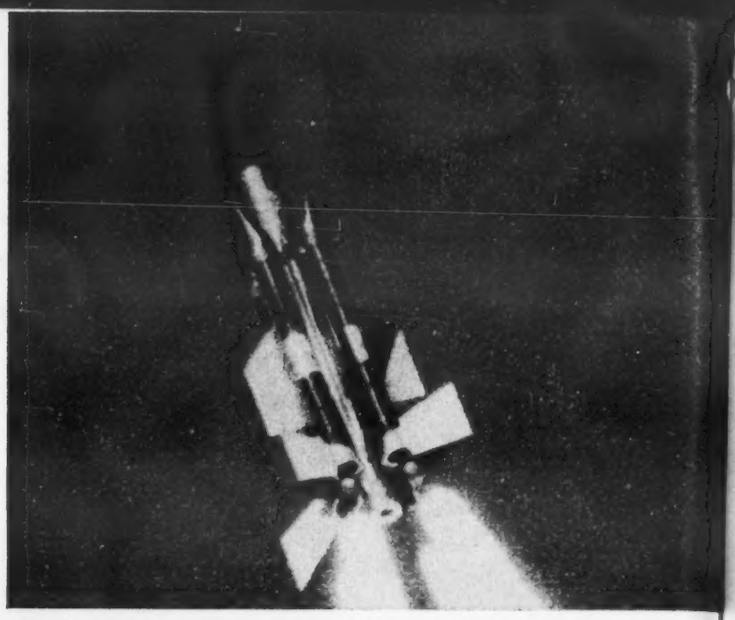


e Clean-wing shape of the future

H AIRCRAFT CORPORATION

TGA BVC 20

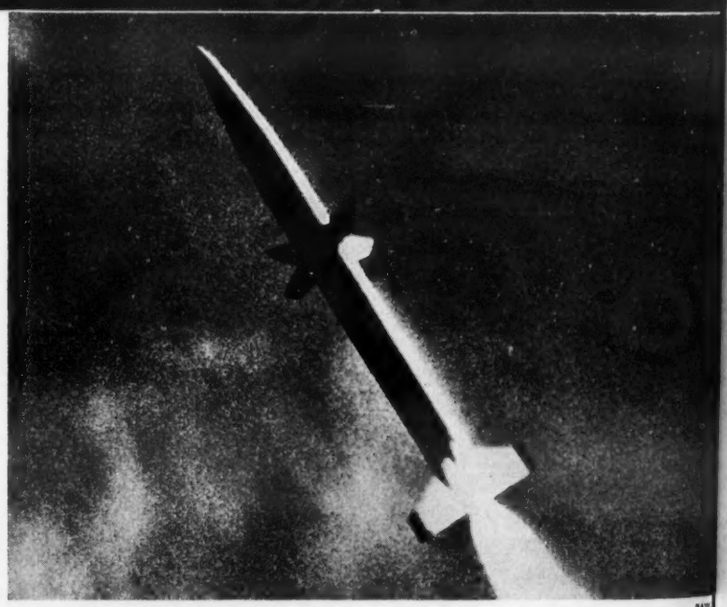
VICKERS **VIGILANT** The Anti-tank weapon which gives the infantryman and the paratrooper the ability to kill the heaviest tank. The *Vigilant*'s auto-pilot ensures the accuracy and ease of control from which stem the highest efficiency and lowest training costs.



'ENGLISH ELECTRIC' **THUNDERBIRD** A fully mobile, solid-fuel, air-transportable ground-to-air missile in service with the British Army. A development contract has been placed for Thunderbird Mark II.

4 GUIDED MISSILES FOR WESTERN DEFENCE

BRISTOL/FERRANTI **BLOODHOUND** A long-range, high-altitude, ram-jet powered, ground-to-air missile adopted by the Royal Air Force, Sweden & Australia. Bloodhound Mark II is now under full development.



'ENGLISH ELECTRIC' **BLUE WATER** This tactical surface-to-surface weapon is Britain's second-generation army missile. It has a solid-fuel motor, inertial guidance, high accuracy, rapid fire power and great mobility.

AND BUILT BY

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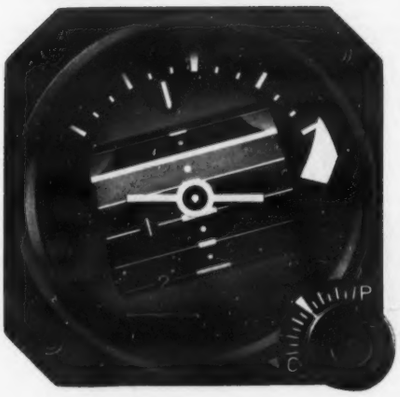
Electronics in Aviation and Industry

What's New in Electronics?



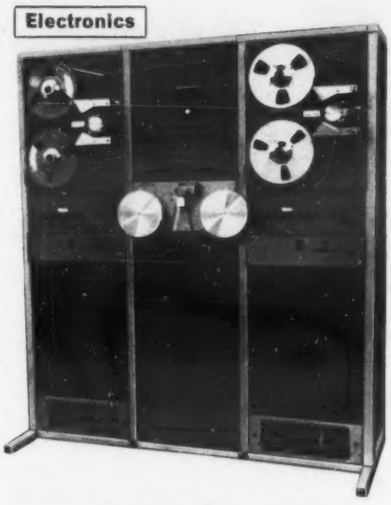
■ **SFENA (Société Française d'Equipements pour la Navigation Aérienne), Neuilly, France,** has announced the introduction of the SFENA type 707 artificial horizon, which has been designed as standby equipment for large jet transport aircraft, such as the Boeing 707 and Douglas DC-8. The instrument is a self-contained panel-mounted unit and works quite independently of the aircraft's central gyro platform. The accelerations during take-off are used to ensure rapid erection and indication of the true horizon. Sensitivity to longitudinal changes of attitude is 1.4 mm per degree, but for special applications this figure can be increased if required.

■ **Hughes Aircraft Company, Fullerton, Calif.,** has developed new equipment for the display of tactical situations, which is intended for use on the latest aircraft carriers and missile-armed ships, as part of the Naval Tactical Data System (NTDS). The positions of all ships, submarines and aircraft of the fleet task force are shown on a screen, so that the command personnel on each vessel have an exact picture of the current situation constantly before them and can concentrate on the job of controlling the ship, assigning the weapons and coordinating operations. The new method eliminates the possibility of error and delay and is thus a considerable improvement on the old charting method (see top section of picture). Following successful tests of the new system by the Naval Electronics Laboratory at San Diego, equipment of this type is now under construction for five ships of the U.S. Navy.

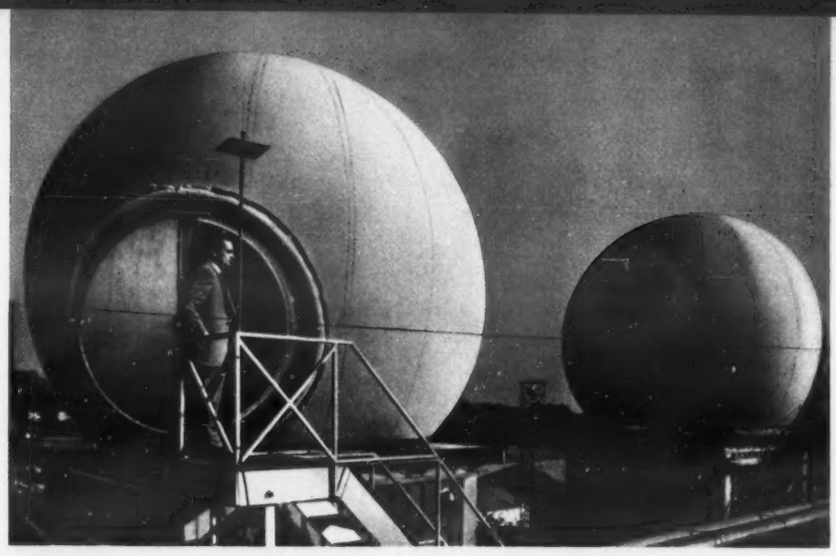
■ **Motorola, Inc., Chicago, Ill.,** has introduced a new VHF pocket transmitter known as *Handy-Talkie*, which can be used in conjunction with static or mobile receivers and also with the VHF pocket receiver (see picture right) recently brought out by the same company. This fully-transistorized transmitter is designed for frequencies between 25 and 54 Mc/s and between 132 and 174 Mc/s. With a power output of 500 milliwatts FR, it has a greater consistent range than similar tube-type sets. The new set measures 5⅛ × 2½ in. and weighs only 14½ oz (including microphone, aerial and battery).

■ **Hughes Aircraft Company, Los Angeles, Calif.,** recently presented the *Mobot II*, a remote-controlled mobile robot, designed to handle "hot" jobs and replace human beings in danger areas (its predecessor, *Mobot I*, is working in the Sandia Corporation's radiation laboratories at Albuquerque, N.M.). The two six-foot steel arms, each with three double joints, are exceptionally mobile. The manufacturer claims that they are strong enough to lift a lead brick, yet the "hands," provided with inflatable pads for sensitive pressure control, are delicate enough to replace a light bulb. In the picture, *Mobot II* is seen in the delicate task of pouring a liquid from one flask into another.

The robot can be controlled from more than 100 ft away, and even from a different room. The speed of the robot, which moves on nearly invisible rollers, and the speed of its arm movements, are regulated by foot-pedals on the control console, all other movements being controlled by toggle switches. Two TV cameras, whose positions can be altered at will, monitor the robot's work. In addition, two microphones are fitted at the "wrists," so that the operator can actually "hear" his machine. Whereas all its forerunners had hydraulic joints, those of *Mobot II*, which has comprehensive electronic equipment, are electrically actuated. The control signals for given tasks are recorded in advance on tapes; these, when played back, enable the robot to perform repetitive functions.



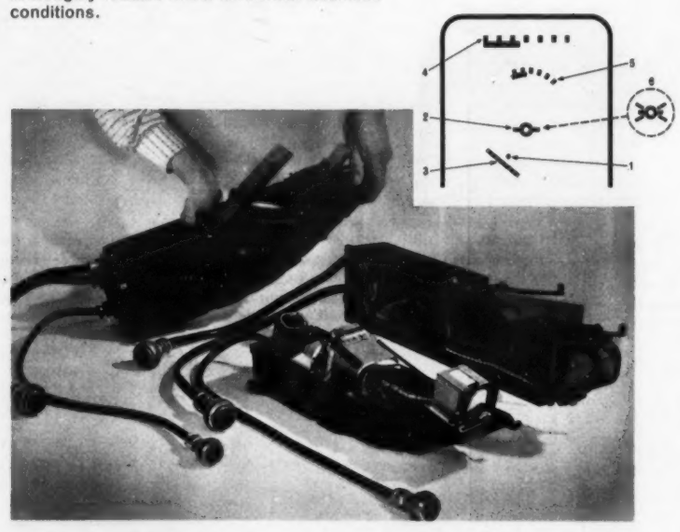
■ **Tally Register Corporation, Seattle, Wash.,** supplies a data system, Model 1433, which transfers data from perforated tapes of various types to magnetic tape. Input and output data are completely identical, no code change being normally performed (a code conversion apparatus can, however, be supplied separately). The output record on magnetic tape is a bit-for-bit image of input perforated tape, and the Tally 1433 can write data on magnetic tape for direct input to IBM 727, IBM 729 Mod. I and Remington Rand computers. The system, complete in itself, comprises a paper tape reader (capacity 120 bits per second), a magnetic tape recorder and the requisite electronic components. All the elements of the Tally 1433 have already proved themselves in other equipment. The data system runs on normal power and is thoroughly reliable under all normal business conditions.



■ **The Goodyear Tire and Rubber Company, Akron, Ohio,** has produced the twin nylon radomes shown in the picture for the protection of the experimental radar antennas operated for the U.S. Navy by the Applied Physics Laboratory of Johns Hopkins University. These radomes are 12 ft 10 in. high and 15 ft 7½ in. in diameter; their new feature is a special metal airlock at the side, whereas conventional radomes can be entered only through the bottom.

■ **Kelvin & Hughes (Aviation) Ltd., Wembley, England,** one of the companies of Smiths Aviation Division, has developed an instrument which combines a conventional airspeed indicator with a new type of display. This instrument, evolved from the one originally developed for standby use in the de Havilland D.H.121 *Trident*, is designed to give maximum readability and clarity. The indicator comprises two pointers, mounted one behind the other, the rear one being longer and indicating the speeds in the lower range. The indicators first traverse the dial together, readings being taken against the outer or low range scale. After the first revolution, i.e., after transition from low to high range, the white tip of the longer pointer disappears behind a raised mask, which simultaneously prevents any further movement of this pointer. The front pointer then continues alone around the dial and shows the high range on a separate scale. Both scales are linear and divided into 5 knot increments. The picture illustrates clearly the difference between indications of 110 knots (left) and 310 knots (right).

Similar instruments are being supplied by Smiths Aviation Division for the Vickers VC.10. These are fitted with an altitude capsule-operated pointer to indicate normal aircraft cruising speed, as well as an adjustable cursor for take-off speed.



■ **Ferranti Ltd., Manchester, England,** has developed AIRPASS II (Airborne Interception Radar and Pilot's Attack Sight System) as a private venture in succession to AIRPASS I, which went into production two years ago. AIRPASS II is not only a bomb aiming system for day and night interceptor aircraft but is also used for navigation. It is slightly larger in size and weight than its predecessor, and the principle of a self-contained interchangeable nose-pack is retained.

The upper picture shows the pilot's attack sight, which is a feature of both versions of the AIRPASS; it provides the pilot with all the information he needs (inset picture) to attack his target. As soon as the target is located by the fire control radar, a computer automatically works out the best attack course. The target appears as a spot (1) which is brought onto the aiming mark (2). The pilot sees the attitude of his own aircraft by means of a bar (3) and can at any time read his distance from the target on the upper straight scale (4) and his approach speed on the semi-circular scale (5). Additional markers (6) are placed above and below the aiming mark, and a warning lamp fitted near the sight gives a danger signal when the aircraft gets too close to the target.

AIRPASS I, the interception system designed for the English Electric *Lightning*, has already been in use by the Royal Air Force for some time, and AIRPASS II will be installed in the export models of the English Electric *Lightning*, the SAAB *Draken* and the Dassault *Mirage III*.

■ **Aviradio, Paris, France,** has brought out the ER-144 series of new VHF transceivers covering the frequency range 108—144 Mc/s. Three types (for civil aircraft, military transport and light aircraft) are in production. These are distinguished by their light weight and small dimensions. The transceiver, which weighs only 8.3 lb including power pack, is easily mounted on the instrument panel or between the pilot seats. There is one model with 720 channels (50 kc/s spacing) and another with 360 channels (100 kc/s spacing). Frequency changing is carried out by means of a simple digital tuner. Consumption is 7 amp on a 12 to 14V power supply and 3.5 amp on 24 to 28V. The power output is 3 or 6 watts (aero club models) and 6 to 8 or 12 to 15 watts (commercial aircraft models).

TARAN

A compact navigation and fire control system

For many years the Hughes Aircraft Company has been engaged in research and experimental work on pictorial navigation displays. As long ago as June, 1954, engineering design was started on an advanced map display instrument, which was intended to present navigation data automatically and continuously. This equipment was described as a Tactical Situation Display (TSD) and integrated the information received from the aircraft VOR/DME equipment, the compass system and the pilot-operated controls. Later models were designed to operate with TACAN in place of VOR/DME.

In October, 1960, the company announced the existence of a new aircraft system called TARAN (Tactical Attack Radar and Navigator) which embodied many of the results of the design work and flight testing which had been carried out on the original pictorial display.

The TARAN system has been developed to give the tactical fighter-bomber the ability to operate in all weathers and to avoid detection by carrying out low-level penetrations below the enemy radar coverage. To provide this capability, it is obvious that the system should present the pilot with complete position information to enable him to navigate to the target and return in any kind of weather, by day or night. At the same time it must provide warning of obstacles which are high enough to endanger the aircraft when flying at low altitude. The third requirement is that the system can work independently of external assistance such as radio transmissions, which are prone to enemy jamming.

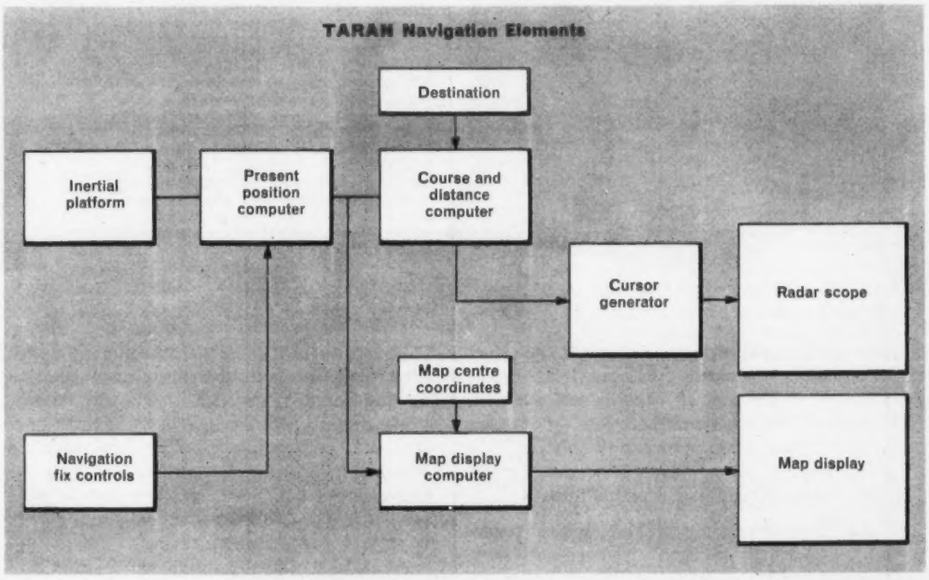
Together with the navigation function, TARAN also provides the pilot with the means to detect ground targets in bad visibility when operating in the tactical bomber role. When employed on interception duties, the TARAN system can perform the search and track functions required to locate an enemy aircraft, and it will launch either radar or infra-red air-to-air guided missiles.

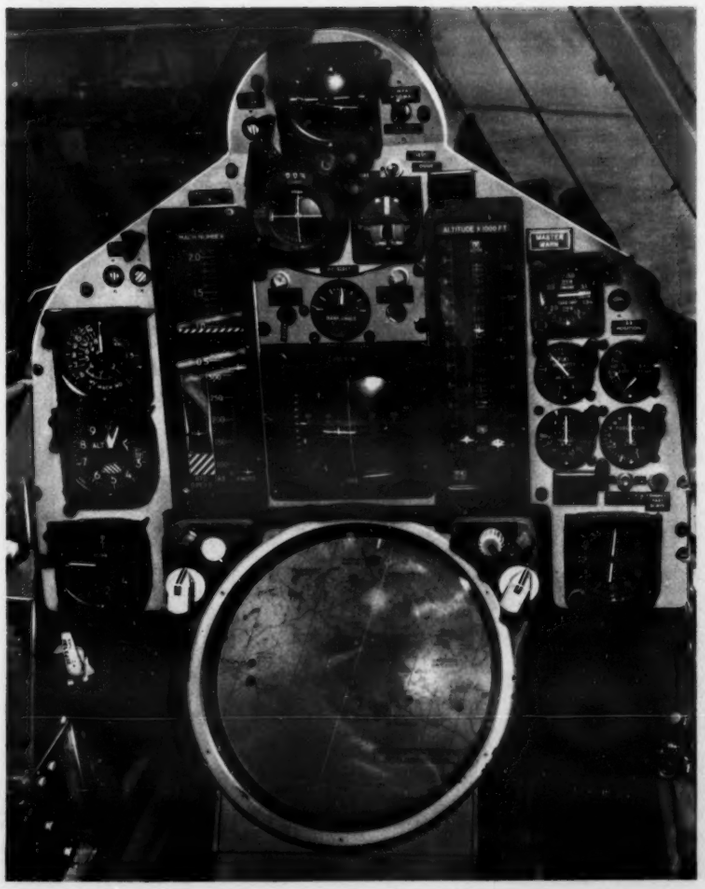
The elements of the TARAN system can, therefore, be considered in two units. The first is the navigation unit and pictorial situation display which gives the pilot a continuous visual indication of his present position and heading, while the second is the radar unit which provides the target ranging facilities in both air-to-ground and air-to-air attack and also supplies flight safety information such as ground clearance and obstacle warning. The radar is also used to correct the computed position information which appears on the map display, by means of ground fixes.

The navigation system

The accompanying illustration is a simplified block diagram of the navigation system. The basic element is an inertial platform which supplies the outputs indicating present position to a course and distance computer. These outputs are also used to drive the map display unit. If it is desired or operationally preferable, a doppler radar navigation system can be employed instead of the inertial platform.

The navigation display is presented to the pilot by means of a composite image optically projected





The prototype Tactical Situation Display which was installed in a modified F-102 cockpit for flight trials in 1957. This installation was originally designed to present information received from the aircraft VOR/DME, but during the flight trials the equipment was converted for use with TACAN. In this version, storage is provided for film charts covering 24 VOR/DME stations. For each station, three maps are available to scales of 50, 100 and 400 nautical miles in diameter. The map remains stationary while the aircraft symbol on the screen moves in relation to the chart.

◀ The navigational display unit of the TARAN system. This unit differs from its predecessors in that the aircraft symbol is positioned at the centre of the display and rotates as the aircraft heading changes. The map is moved at a speed and in a direction relative to the aircraft velocity. The drawer beneath the dial contains the automatic map slide holder.

The experimental Tactical Situation Display illustrated here was used in a flying laboratory test programme for nearly two years, beginning in January, 1956. The display screen carries the following symbols: 1. Command heading; 2. Aircraft symbol indicating aircraft position and heading; 3. Fuel range circle indicating maximum flight range; 4. Target symbol; 5. Aircraft heading read from the periphery of the screen. The switch on the upper left-hand corner of the instrument selects the chart diameter scale. ▶

on a circular ground glass screen. At the centre of the screen, a symbol indicates the present position of the aircraft, and is automatically rotated to indicate existing heading. The display appears as if the pilot were facing north with the aircraft and ground beneath him, and provides continuous position and course information.

To produce the map display, special photographic slides are prepared from standard aeronautical charts. A system of servos drives the slide so that the optical display moves as the aircraft moves, and the speed of map movement is proportional to the aircraft speed.

The map slides can be marked with the intended route prior to flight and are stored in a semi-automatic slide changer located inside the map display unit. In flight the pilot selects the desired slide by means of a control knob on the display unit and aligns the slide to null errors due to angular misplacements of the slide in the servo driven slide holder. At the same time he inserts the coordinates of the map centre into the map drive computer. The map slides are prepared so that the centres are simply integer degrees of latitude and longitude, to facilitate the insertion of the coordinates in the computer.

In the normal mode of operation, the map drive computer compares the present position, derived from the inertial platform, with the map centres, converts to distance over the earth's surface, and produces latitude and longitude displacements to drive the latitude and longitude motors of the map slide drive. These computations are automatic and result in a continuous motion of the map as the aircraft moves.

At present, the map slides are prepared from standard 1 : 1,000,000 aeronautical charts. They provide a picture of 40 miles radius on the display screen, and each slide covers an area 270 nautical miles square. Alternative types of charts can be employed if necessary to fulfil the tactical requirements of the aircraft's operation.

In operation, this moving map display provides the pilot with continuous information of his position. Any accumulated error in the navigation computations can be nulled en route by the use of visual or radar checkpoints. To make a visual correction, the map is repositioned by manual controls so that the aircraft symbol appears over the ground feature used as a checkpoint. The corrected position is then fed automatically to the computer, which then recommences operation with zero navigation error.

A cockpit mockup containing elements of the TARAN system is seen here installed in a T-29 flying laboratory. A long programme of flight and reliability trials has been carried out on the system.

The radar unit

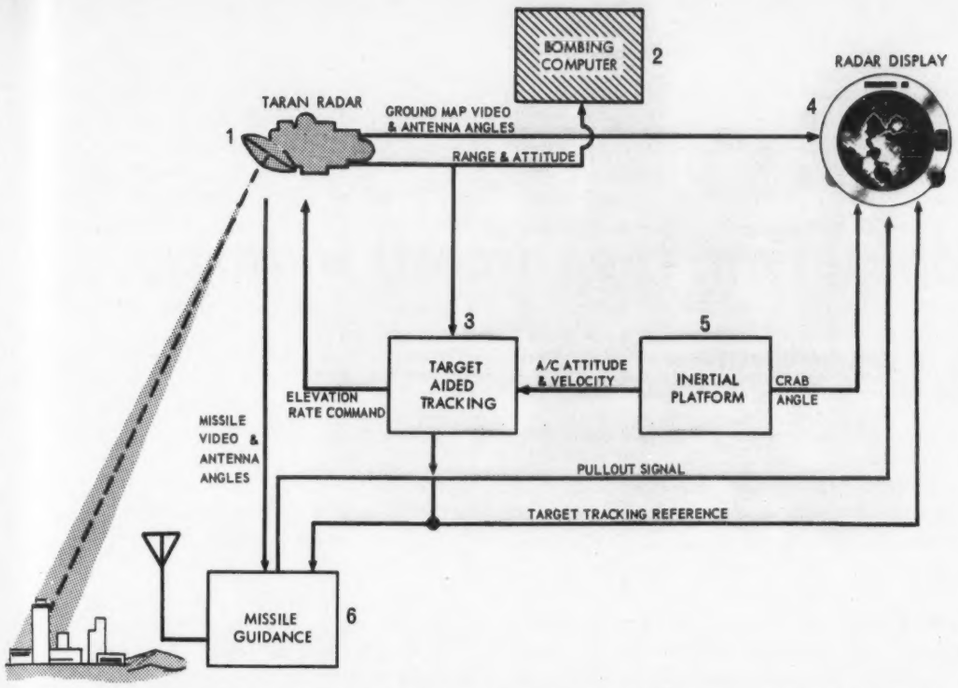
To complement the inertial navigation unit of TARAN, a high resolution radar operating at high microwave frequencies and with a short radar pulse, is used to map the ground over which the aircraft is flying. The radar is employed for a variety of functions to give the tactical aircraft complete all-weather capability. These functions include ground mapping, terrain avoidance, air-to-ground and air-to-air search, missile launching and tracking, and toss, loft or over-the-shoulder bombing.

When used for navigation, the radar display gives a sharp, clearly defined picture of the ground on the radar screen. By using radar checkpoints, any accumulated error in the navigation computations can be eliminated from the automatic navigation system. The expected position of a preselected checkpoint as computed by the automatic navigator is shown on the radar display. This position can then be compared with the actual position of the checkpoint as determined by the radar system, and a correction made by simply pressing a button. It is not necessary to fly directly over such a checkpoint, but merely within radar range of it.

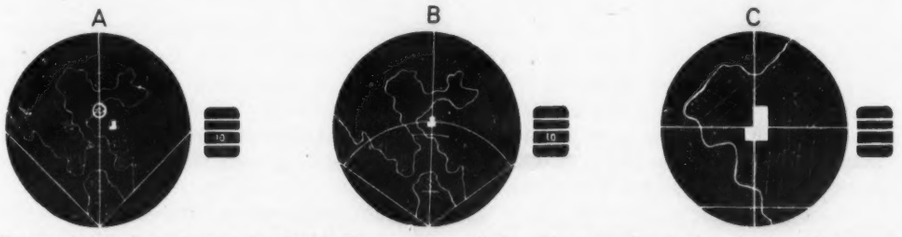
A further mode of operation is that of terrain avoidance. This is employed for low-altitude missions in conditions of bad or zero visibility. In this mode the radar will respond only to echoes from ground obstacles which are above a preselected altitude and which present a danger to the flight of the aircraft. The pilot can then see these potential dangers clearly on the radar display without their being obscured by unwanted ground responses.

Air-to-ground attack

The installation of a navigation system which gives the fighter-bomber aircraft all-weather navigational capability is only a part of the problem of providing complete operational flexibility. Having navigated to the target area, the next stage is to identify the target and deliver the weapon with accuracy. The TARAN system provides steering information to the pilot to ensure that after the target has been identified either from the radar map or visually, the ground

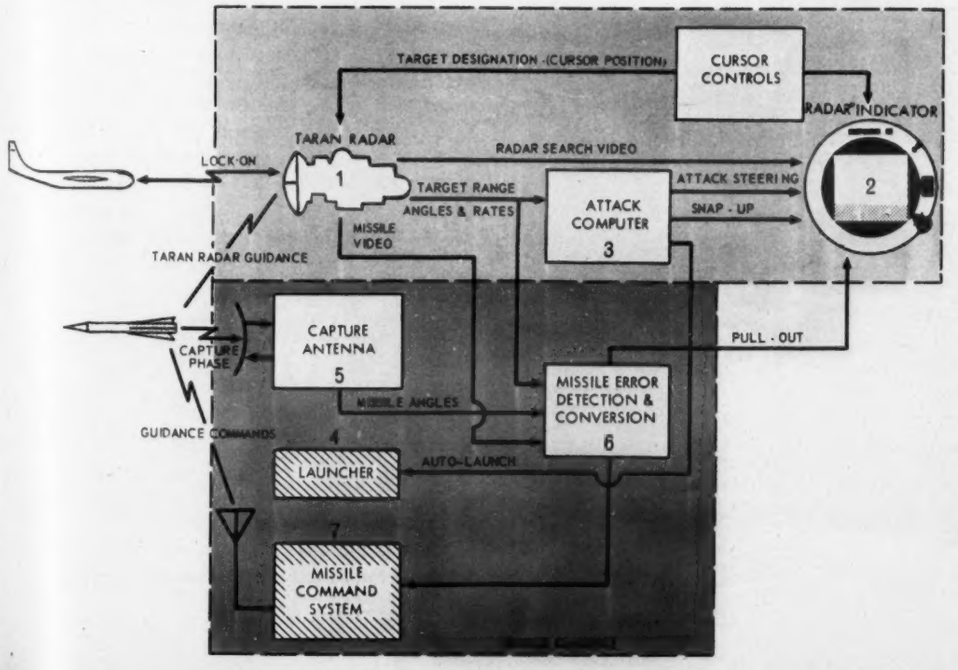


The functional diagram of the air-to-ground attack mode. From the radar unit (1) target range information is passed to the bombing computer (2) and the target tracking unit (3), while the ground mapping information is transmitted to the pilot's radar display (4). The inertial platform (5) supplies aircraft altitude and velocity signals to the tracking unit (3) and crab angle indications to the radar display (4). The target tracking unit (3) provides guidance commands to the missile guidance unit (6), which supplies the tracking reference and pullout signal to the display and also transmits the corrective guidance commands to the missile.



Three typical displays as seen on the radar. A. The ground map display with a target directly along the aircraft's course; B. The pilot has adjusted the ranging cursor to intersect the target position. This feeds the target range to the bombing computer; C. The expanded display for the attack phase. The range cursor is now represented by the straight centre line.

In the air-to-air attack mode, the TARAN equipment can be considered in two sections. The upper part of the diagram is the radar guidance, while the lower is the missile guidance. The radar unit (1) passes the search information to the radar indicator (2). After the target has been detected and the radar has locked-on, the target range data are passed to the attack computer (3) which indicates the attack course on the radar display. At the correct moment the attack computer initiates the launching of the missile by a signal to the launcher (4). After launch, the capture antenna (5) receives the reflections from the missile which is illuminated by the TARAN radar. These signals are passed to the missile error, detection and conversion unit (6) which transmits the corrections through the missile command system (7).



heading will pass through the target. The radar antenna is then auto-precessed to stay on the target, while the pilot monitors the display and corrects the antenna direction as required. If guided air-to-ground missiles are being employed, the radar tracks the missile in flight and compares its position to the target position. Guidance commands are then transmitted to the missile through the TARAN guidance circuits.

When used for bombing, the radar passes the target range information to the bombing computer. The computer calculates the release point of the bomb in relation to the method of delivery employed and indicates the pullout point to the pilot.

Air-to-air attack

The TARAN system can also be used for air-to-air interception and attack. In this mode the radar searches a zone ahead of the aircraft and when the target is detected automatically locks-on and commences tracking. After lock-on, the radar passes the target range, angles and rates to the attack computer which transmits the attack steering commands to the pilot's radar display. As the range between the interceptor aircraft and the target closes, a pattern appears on the radar display indicating that the attacking aircraft is within range; the missiles are then launched automatically, in response to a command from the attack computer. Successive symbols appear on the pilot's display, indicating the moment of missile launch and the command to break off the attack.

After launching, the missiles are tracked by means of a capture antenna which receives radar echoes reflected from the missile. The capture antenna signals the missiles' angles to a missile error detection and conversion unit which in turn transmits corrective guidance commands back to the missile through the missile command system. The air-to-air attack pattern is therefore almost completely automatic, the pilot's duty being primarily to maintain his aircraft in position to illuminate the target with the TARAN radar.

Operational reliability

In the design of the TARAN system, the engineers have paid particular attention to the problems of maintenance and operational reliability. Throughout the design programme, searching analyses have been carried out on component performances. Statistical records of component reliability maintained over the previous ten years on operational Hughes systems were compared with detailed TARAN requirements. New components, on which statistical data were not available, were subjected to rigorous life tests to discover potential weaknesses.

To ensure maintenance simplicity and also to enable the system to be serviced without the requirement for highly skilled crews, the layout has been designed on a pattern of modules. Circuits are divided so that if a malfunction should occur, the faulty unit can be readily identified and replaced. The daily testing of the system can be carried out by manipulation of the cockpit controls, so that a test signal is injected into the circuits and returns to the cockpit displays. By observing the displays the operator can immediately determine the correct functioning of the system.

This regard for simplicity in maintenance is indicative of the fact that the design engineers were very much aware of the hazards of a fighter-bomber's existence. In operational conditions, such aircraft operate from hastily prepared and ill-equipped landing grounds and with a minimum of maintenance personnel. A complex, highly intricate, electronics system has no place in such surroundings, and the fact that this situation was appreciated in the early stages of the design is evidence that the system merits the name of *Tactical* Attack Radar and Navigator. ←→

Analogue Computers in the Aircraft Industry

By Dr. W. Giloi, Telefunken Computer Centre, Constance,
and Dipl.-Ing. E. S. Schoen, Bölkow-Entwicklungen, Munich

Nowadays electronic computer installations are indispensable aids in the design, stressing and testing of aircraft, but the wide variety of problems encountered in all fields of aeronautical engineering rules out a clear-cut choise between the analogue and digital types. In fact each has its own special field of application, in which it excels, and it has lately become increasingly apparent that the best procedure is to link them up and so combine their advantages. The analogue computer, with which this article is concerned, whilst less suitable for solving algebraic problems, is highly efficient at the high-speed integration of time functions and thus in solving differential equations.

This gives the aeronautical engineer an ideal tool for use in calculating the behaviour of airframes and in solving problems of stability and control, with all the accuracy offered by a modern D.C. analogue computer. Moreover, the analogue computer functions at such high speed that all kinematic phenomena can easily be measured in real time.

It is thus possible to simulate the behaviour of airframes by the input of data relating to specified control functions (such as adjustment of control surfaces and changes in thrust), the computer giving independent output of data describing the current flight situation (such as the velocity in trajectory and position in relation to the reference system). Ideally, it should not be possible to tell whether the final results have been obtained from a computer or derived, after necessary processing, from an actual airframe. At present, however, this applies only to analogue computers as the digital types available function too slowly (see *Interavia* No. 6/1960, p. 738–739).

It is hardly necessary to stress the value of being able to simulate real conditions and to make an unlimited number of tests inside the laboratory. The use of an airframe for this purpose is laborious, costly and often dangerous and generally far from justified by the value of the results obtained. A rocket constructor with an analogue computer in his laboratory has, so to speak, an inexhaustible supply of rockets ready for launching and can at any time simulate extreme conditions under which to test and perfect, say, their directional system. The cost in time, effort and money of even a few tests carried out with an actual rocket will generally pay for a computer.

What components are essential in a computer intended for solving aeronautical engineering problems? This question can only be answered by a closer look at the basic equations governing the movement of an airframe. To begin with, two reference systems must be clearly distinguished. These are the geodetic reference system (in which the airframe moves) and the so-called normal system which moves with the airframe whenever the latter turns about its longitudinal axis and includes all movements arising from internal forces (such as lift and control moments), the only external force, weight, being inserted into the system. In this way the conversion of purely airframe data into the space coordinates is avoided. It is only after the completion of the calculation that the results are transformed into the geodetic reference system.

An aircraft is able to move along the three axes of a system of fixed coordinates as well as to rotate about them, and its six degrees of freedom can accordingly be described by a set of six differential equations—roll, pitch, yaw and vertical, forward and sideslip movements. In addition there are the geometrical relationships for the angle of incidence; $\alpha = \vartheta - \gamma$ (where ϑ = angle of pitch and γ = flight path angle), and for the angle of sideslip $\beta = \psi - \chi$ (where ψ = angle of yaw and χ = angle of lateral flight path). In some cases it is also necessary to convert from the normal to the geodetic system.

The coefficients of these six differential equations are partly dependent on the varia-

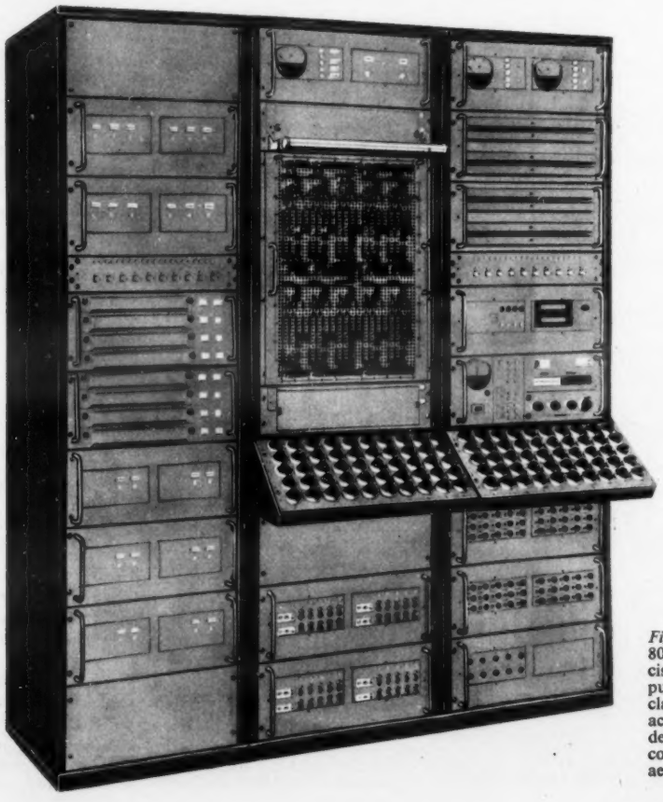


Fig. 1: Telefunken's RA 800 fully transistorized precision analogue computer, in the 10^{-4} accuracy class. The components and accuracy of this model are designed for solving the complicated problems of aeronautical engineering.

bles themselves, and the equations are therefore non-linear. Strictly speaking, these coefficients should be regarded as functions of several variables, but in practice they can always be represented by a Taylor series as functions of one variable. Under "normal" flying conditions the angles are always so small that the coefficients themselves can be taken as constant. In order to represent extreme conditions (such as in the case of VTOL aircraft and rockets) the number of function generators in the analogue computer may, however, have to be increased in certain circumstances.

As regards the units to be included in a computer required for solving the system of equations governing the general movement of an airframe, we have already seen that for conversions from the geodetic to the normal system (and vice versa) the coordinates must be transformed. Such transformations are performed by the resolvers (one for each of the two transformations). Two further resolvers are needed to divide the thrust into its components (longitudinal force and lateral force).

For integrating the differential equations, at least thirteen integrators are required, and for multiplying the variables by the coefficient functions up to six servo-multipliers, depending upon the type of equipment. In addition, there is need for a number of operational amplifiers. As a rule of thumb, there should be twice as many adders as integrators, the exact number required being determined by the way in which the individual terms of the equations are expressed.

The manufacturers of analogue computers study each customer's requirements and provide the appropriate components in each machine. In the case of calculating machines with interchangeable patch panels, the maximum number of units (bricks) depends on the capacity of the patch panel, but on the other hand there is nothing to prevent the linking of several computers of this type. Telefunken's new fully-transistorized precision analogue computer RA 800 *(figure 1)* has a maximum capacity of 100 potentiometers, 64 amplifiers (26 of which can add or integrate as required), 8 electronic multipliers, 8 electronic function generators, 10 comparators, 4 servo-resolvers, 8 servo-multipliers/function generators with up to 4 products/functions each. With an installation of this type, it is possible to carry out a simulation and calculate the general movement of an aircraft in space, while still leaving some units in reserve, either for developing the problem or for other calculations.

However, there still remain various important problems beyond a computer of this kind. In the example shown in the box, the thrust is assumed to be constant and deflections of the control surface are taken as fixed. In many cases, however, a number of additional factors must be taken into consideration. Such factors include relationship between thrust and speed in propeller and ramjet aircraft, changes of weight and shifts in the centre of gravity in rocket vehicles, and in a general way, the influence of the Mach number and of changes in atmospheric density. In stability tests on airframes with free control, an extra degree of freedom and consequently an extra differential equation sometimes arise. It is, however, probably the general flight simulator, as used for pilot training, which makes the greatest demands on the computer, since in this case the extremes in flying and operational conditions must be simulated.

Yet there is often a requirement to represent not merely the airframe itself but whole systems. An example of this is an airframe operating with an automatic stabilizer or with auto-

What a small computer can do

The object of this example is to investigate the longitudinal movement of a fast fighter-trainer (delta-winged, flight speed 270 m/sec) in response to an abrupt displacement of the elevator (applied and corrected within one second). In this problem it is assumed that, prior to commencement of the disturbance, the aircraft was in horizontal flight ($\gamma = 0$) and is in motion about its pitch axis only (without roll or yaw). Only five values need therefore be taken into consideration, namely path speed v, path angle γ, angle of inclination (along the longitudinal axis) ϑ, angle of incidence α, and elevator displacement β. For these the following basic equations can be established:—

$v = v_0 + \Delta v$; $\gamma = \gamma_0 + \Delta\gamma$; $\vartheta = \vartheta + \Delta\vartheta$; $\alpha = \alpha_0 + \Delta\alpha$; $\eta = \eta_0 + \Delta\eta$.

Since, in accordance with the original assumption, the deviations are only small, we can therefore go on to say:—

$\sin\gamma = \sin\gamma_0 + (\cos\gamma_0)\,\Delta\gamma$

and

$\cos\gamma = \cos\gamma_0 - (\sin\gamma_0)\,\Delta\gamma$

and we thus arrive at the following system of equations

$$\frac{G}{g}\cdot\frac{d\Delta v}{dt} = \frac{\rho}{2}v_0^2 F\cdot c_{W0}\,2\frac{\Delta v}{v_0} - \frac{\rho}{2}v_0^2 F\cdot c_W{}'_\alpha\,2\alpha_0\Delta\alpha - G\cos\gamma_0\Delta\gamma$$

$$\frac{G}{g}v_0\frac{d\Delta\gamma}{dt} = \frac{\rho}{2}v_0^2 F\left(c_A{}'_\alpha\Delta\alpha + c_A{}'_\eta\Delta\eta\right) + S\Delta\alpha +\Big)\frac{\rho}{2}v_0^2 F\left(c_A{}'_\alpha\alpha_0 + c_A{}'_\eta\eta_0\right)2\frac{\Delta v}{v_0}$$

$$J_y\frac{d^2\Delta\vartheta}{dt^2} = c_M{}'_\vartheta\cdot l^2\cdot\frac{\rho}{2}v_0^2 F\frac{d\Delta\vartheta}{dt} + \frac{\rho}{2}v_0^2 F\left(c_M{}'_\alpha\Delta\alpha + c_M{}'_\eta\Delta\eta\right) + \frac{\rho}{2}v_0^2 F\left(c_M{}'_\alpha\alpha_0 + c_M{}'_\eta\eta_0\right)$$

$$\alpha = \vartheta - \gamma$$

To solve this problem, four integrators, two adders, and nine potentiometers are sufficient. Illustration *2a* shows in graph form the variations in speed (one graduation representing 1.5 m/sec) and illustration *2b* the alteration in path angle (one graduation representing 0.01 radians) as a function of time *(t)* (one graduation representing 10 seconds).

If $\Delta\alpha$ is extracted from the computer system it is seen that this value remains one degree of magnitude smaller than $\Delta\vartheta$ and $\Delta\gamma$, therefore $\Delta\gamma \approx \Delta\vartheta$. Phugoid movement of this kind is characteristic of aircraft with a relatively high moment about the angle of incidence, the weak damping of the oscillation being typical. In some instances, where damping is too weak, automatic stabilization must be used, since the low drag coefficient characteristic of high-performance aircraft militates against natural stabilization.

Fig. 2a: Variations in speed Δv of a fast fighter-trainer in response to an abrupt displacement of the elevator (applied and corrected within one second). One graduation represents 1.5 m/sec.

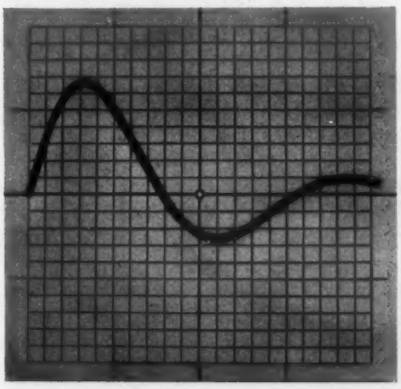
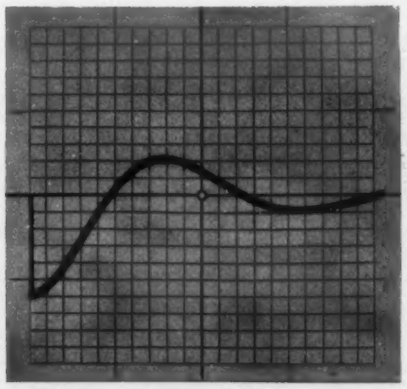


Fig. 2b: Alteration in the path angle $\Delta\gamma$. One graduation represents 0.01 radians. Time scale: one graduation represents 10 seconds.



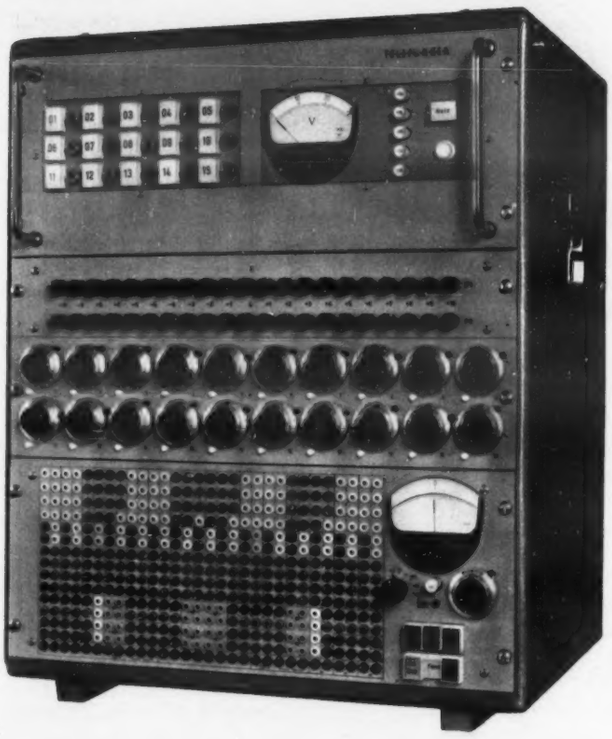


Fig. 3: Telefunken's RAT 700 Desk Analogue Computer comprises 15 amplifiers (of which 8 operate as integrators or adders, as required), 4 multipliers, 2 function generators and 20 potentiometers. It can perform the most important operations of larger computers, such as continuous calculation and repetition, with a limit of error of 10^{-3}. A special advantage is that these computers can be linked as required to form larger units.

matic directional control (autopilot or remote control system).

The analogue computer is admirably suited for solving all such problems in real time owing to its extreme flexibility and freedom from basic limitations. The systems under investigation may be non-linear and complex, provided that the necessary units (bricks) are available. For still more complex problems, larger computers are required.

On the other hand, there are many problems for which the full capacity of the RA 800 is certainly not required. This is particularly the case with stability tests which are usually carried out by the so-called small disturbance method, only minor deviations from the state of equilibrium being taken into consideration. This enables equations to be linearized to a great extent. The six degrees of freedom can be divided into two separate systems, each with three degrees of freedom, thus allowing separate consideration of longitudinal and lateral movements (see box). Many tests of this kind can be carried out with relatively small computers. For the development of specific components of airframes, of propellants, and of control systems, a smaller computer will usually be sufficient, but this should be kept constantly available at the development centre for experimentation or for simulation of various parts of the system.

To meet the latter need, so-called desk computers have been developed. These are fully transistorized throughout and, depending on the type of problems to be solved, the components have an error of 1 per mil. Telefunken's Desk Analogue Computer RAT 700 (*figure 3*) is an example of this type. It comprises 15 amplifiers (of which 8 operate as adders or integrators as required), 4 multipliers, 20 potentiometers, and 2 function generators. It is equipped with a central patch panel and can perform the most important operations which a larger computer carries out, namely exact repetition, continuous calculation and storage. Desk models can be linked as required to form larger units under central control.

It is often asked whether the basic conception of the analogue computer of today will change, and the answer is that the basic techniques of conventional calculating units are unlikely to alter fundamentally. There is however, no doubt that the future will see a much closer connection between analogue and digital computers and methods. At the moment the main development in analogue computers results from the change-over from tubes to semi-conductors and the introduction of printed circuit techniques. Indeed, over the last two years, the only new development in the market has been the appearance of transistorized computers which are much more reliable than conventional types, occupy about a third of the space and use a fifth of the current. The small amount of heat generated and the much lower power requirement obviate air conditioning, and ensure that the modules work accurately for long periods with an all-important resulting gain in overall precision. The transistor types are equally as accurate as the former tube models, and in some respects considerably more so.

This is particularly true of the multiplier, for long the computer's weak point. Electronic "time division" multipliers call for very exact electronic switching, a requirement which the transistor meets very much better than the tube. In the electronic multipliers of Telefunken's analogue computer, RA 800, product error is 2.10^{-4}, and the zero point error 3.10^{-5}.

Analogue computer technology has undoubtedly acquired great importance in the aeronautical engineering world, particularly in its newer fields. For their part, aeronautical engineers have not been backward in making fruitful contributions to computer technology, whether by developing specialized supplementary equipment, such as function generators and servo-systems or by adding to existing computing techniques, for example the method of dealing with "adjoint systems." This exchange of ideas is of great value to the development of the analogue computer in all its many applications. →→

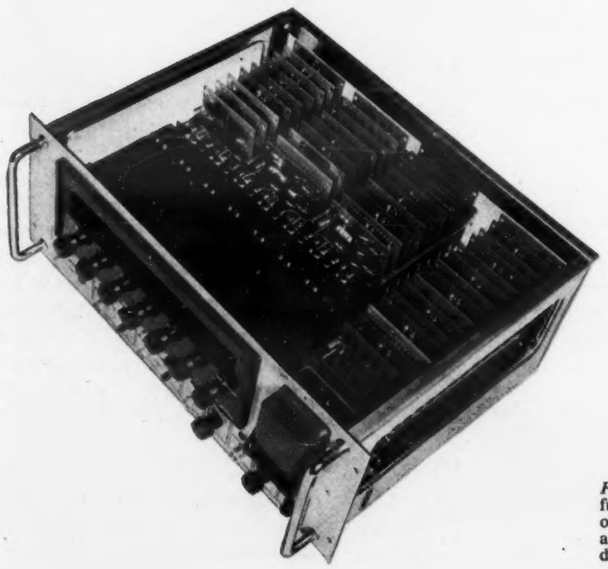


Fig. 4: Upper section of a Telefunken universal computer based on latest printed circuit techniques and using exclusively semi-conductor diodes and transistors.

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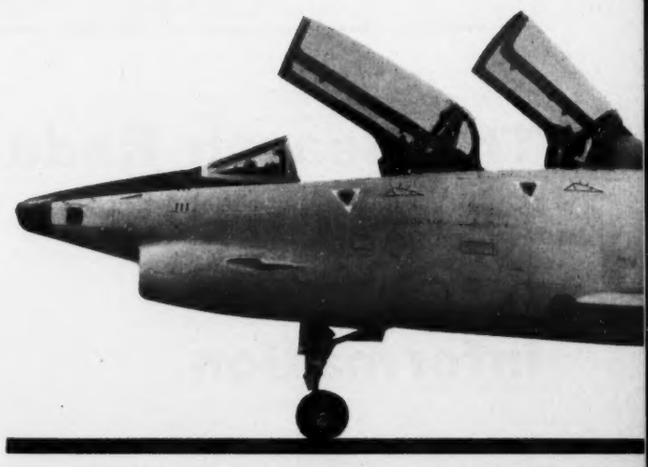

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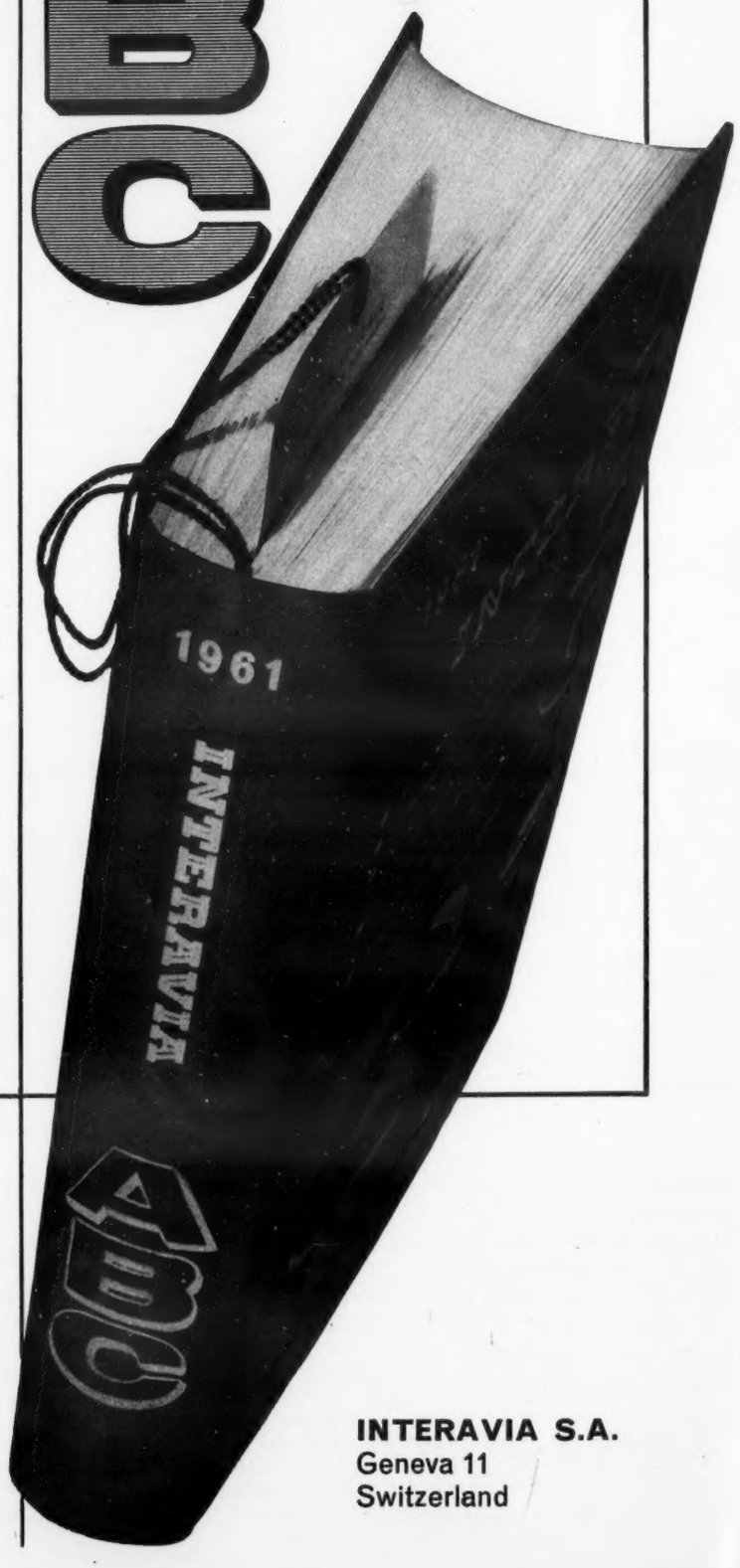

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USAF Troposcatter System to Link England to Africa

Construction of a multi-million dollar troposcatter communication system primarily intended for use by the U.S. Air Force is beginning in Spain. This will provide high-quality voice communications between Morocco, Spain and England.

The prime contractor, Page Communications Engineers, Inc., a subsidiary of Northrop Corporation, has set up a field office in Madrid to control overseas operations and is working closely with U.S. Government agencies in Spain who are responsible for building work required by the project. Equipment to be used has been ordered from various manufacturers in the U.S. and overseas. Deliveries should begin within the next few months and will be timed to coincide with the completion of the building programme.

While the coordination and supervision of all the work in Europe is in the hands of Page's field office, planning is carried out by the company's headquarters in Washington. The latest advances in telecommunications were incorporated in the development of the system, giving it considerable advantages over others in the same area.

The project incorporates the earlier *Senorita* tropo circuit between northern Africa and southern Spain, which was completed in 1958 and improved last year to match the new network. In the new system, the first link from southern Spain goes northward approximately 250 miles. From there the next link extends to a mountain-top site on the north coast of Spain. The path length for this hop is approximately 200 miles. From the northern Spain site, the final and longest link is over 500 miles to a point on the southern coast of England. Connections with a commercial telephone system from this point will permit distribution of telephone circuits to air bases in England. Similarly, in Spain, facilities are provided at each location for entry into the system by Air Force subscribers, so that direct telephone service is afforded between any two points in the network.

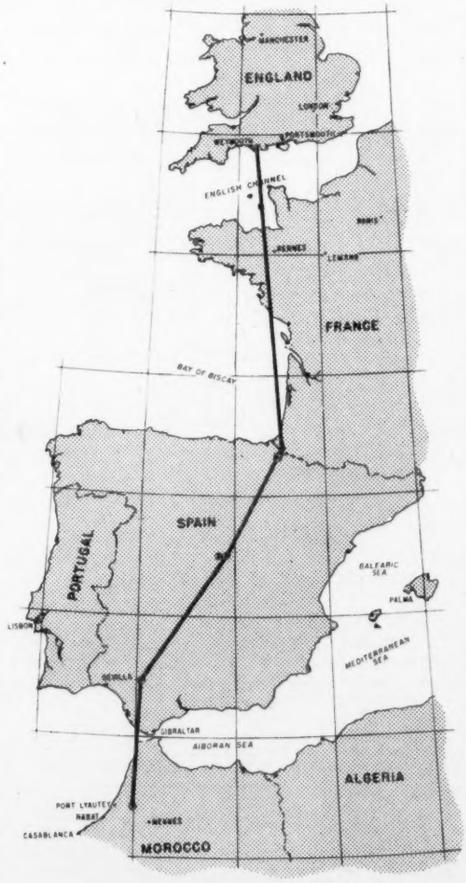
The basic equipment to be used in the system is the AN/FRC-39(V) tropospheric scatter radio terminal manufactured by Radio Engineering Laboratories of New York. This complete transmitter-receiver set, similar to that being procured for BMEWS, uses frequencies in the 755 to 985 Mc/s region. The high-reliability FM equipment uses parametric amplifiers in the front ends of the receivers and is designed conservatively to provide the very favourable intermodulation distortion figure of 55 db between adjacent channels. The FRC-39(V) contains its own exciters and quadruple diversity receivers as well as a 10 kW power amplifier, and is thus practically a complete communications terminal within itself.

The FRC-39(V) will be used on all links of the Spain-Morocco project at a 10 kW power level, but not for the estimated 500 mile path between England and Spain, where more power is needed. Using the tropospheric scatter mode of communications, maximum power at this frequency is necessary for an extreme path length of this size. At first 50 kW was thought to be maximum power obtainable, but developments since the project began have shown that 75 kW is possible. A high-power amplifier using a Varian klystron capable of providing 75 kW is being built for use on this project by Levinthal Electronics Company. This will be integrated with the rest of the FRC-39(V) package to provide transmission equipment for the long path. At first only 24 voice channels will be available on this section, but the system can be built up step by step to a full capacity of 240 channels.

The multiplexing equipment to be used with the FRC-39(V) will be a frequency division type designed and manufactured by Siemens & Halske. This equipment, similar to that used on U.S. military communications circuits in Germany and to that purchased by RCA for use on the Spanish microwave system, provides 24 voice channels in two 20 in. cabinets. This equipment has already proven itself in service in Germany and on the *Senorita* circuit, where it was installed by Page some months ago as a first step in the overall project.

Outside plant equipments to be used are 60 ft and 120 ft billboard antennas built to meet stringent military specifications. The latter are such that the antennas must withstand 175 m.p.h. winds and six inches of ice while maintaining extremely close deflection tolerances. These antennas were manufactured in England by Blaw-Knox and were scheduled to arrive for erection on the site by the end of last year. Foundations and anchors are being prepared by the construction agency in Spain.

From summer 1961 onwards troposcatter networks will provide fully automatic telephone communications between USAF bases in Morocco, Spain and Britain.



Adding to the problems of this long hop are natural geographic difficulties. The northern Spain terminus is a splendid site from a radio standpoint but not the easiest for erecting buildings and skyscraper antennas. It is mostly rock, and is swept by high winds and thunderstorms during the summer and violent snowstorms in the winter. It is approximately fifty winding miles to the nearest town, which provides most of the modern facilities necessary for the job, including living quarters for the men. From there it is over a hundred miles by twisting mountain roads to the nearest Air Force base from which supply support will come.

The other sites in Spain do not present the problems of the northernmost site. One lies on a flat-topped mesa near an ancient Spanish town which this year is getting its first running water from a newly dug cistern near the site marked for the new tropo building. Its location provides ideal radio paths in three directions, which is fortunate because it will serve as a junction point with another future tropo system heading eastward across the Mediterranean. The main building, housing the electronic equipment, will be large enough to accommodate three complete tropo terminals and an automatic telephone switching centre. Primary power will be furnished by diesel generators installed in a separate building.

The southernmost site in Spain is on a Spanish airfield which serves as a municipal airport for the local community. It is close to the existing tropo site for the circuit to northern Morocco and also to the USAF Communications Relay Center, which are both located at San Pablo. The nearest USAF station is about 40 miles away.

Another feature of the fixed plant complex being installed in the U.K. and Spain is its incorporation of automatic switching facilities in a channel control centre to be installed at a site near Madrid. This will be the latest switching equipment manufactured by North Electric Company. It will make it possible for a subscriber anywhere in the air base complex to reach any other subscriber simply by dialling a set of code numbers. Operators will be available for assistance and special purposes but normally will not be required for placing ordinary calls. Signalling equipment of the CV-566 type as manufactured by Lynch Electric Corporation for the U.S. Army Signal Corps will be used to activate the automatic switching equipment.

As part of its basic contract, Page will continue to operate the entire complex for a year after completion. The company is currently operating the *Senorita* portion of the system and will use the same methods on the rest of the system when completed. Special studies will be made of circuit performance over certain parts of the complex to determine its efficiency and capabilities. Page also hopes to evaluate much of the scientific theory used in planning and engineering site locations, Fresnel zones, antenna design and many other matters of absorbing interest to radio engineers. The system is expected to be on the air by summer this year.

Telecommunications with Satellites

Jacques Fagot, Technical Manager, Telecommunications Division, CSF, Paris

Satellites are launched into space for a definite purpose, in most cases scientific measurement, and it goes without saying that radio communications play a vital part in their successful operation. It is desirable that the results obtained should be made available to the interested scientists immediately and without waiting for recovery of the vehicle, which is in any case always a matter of uncertainty.

It is also important to be kept informed as to the position of the satellite itself, especially should it be lost to visual observation, and this can be done by means of radio bearings on the satellite's signals. The vehicle can also be made to alter course by active intervention in the form of telecommand signals.

Some satellites have the special function of acting as intermediate relay stations in earth-to-earth links, and in a set-up of this kind the part played by telecommunications is even more telling.

Formula for Transmission in Free Space

It is a long time since radio engineers calculated a formula for transmission in so-called free space, that is space free of all obstacles. They were, however, limited to the earth's field, where it was almost impossible to achieve ideal conditions. All this was changed by the advent of satellites, which provided a first-class practical example of this type of transmission.

According to this formula, power received P_r at a point R at a distance d from the transmission point E can be expressed thus:

$$P_r = P_e \frac{\Sigma_1 \Sigma_2}{\lambda^2 d^2} \qquad (1)$$

where λ is the wavelength of the radiation used, P_e the power emitted and Σ_1 and Σ_2 the radiating surfaces (antennas). The latter are, strictly speaking, equivalent surfaces, which differ slightly from the true geometric surfaces in each case.

In this type of transmission, the effective energy is always very low, e.g., one millionth or even less, and formula (1) shows us three ways in which this can be improved. These are by enlarging the antenna surfaces, by reducing the wavelength and by raising transmission power.

Any enlargement of the antenna surfaces is necessarily accompanied by an increase in directional properties, the radiation being emitted along an increasingly narrow beam. The one serious difficulty arising in this connection is that of accurately aiming the antennas, where the satellite is mobile.

Attenuation caused by the earth's atmosphere

As one of the terminal stations is normally situated on the ground, the beam transmitted or received inevitably passes through the various layers which constitute the earth's atmosphere, namely the troposphere, the stratosphere and the ionosphere. Taken together, these form a kind of attenuating screen, which the beams penetrate at a more or less oblique angle.

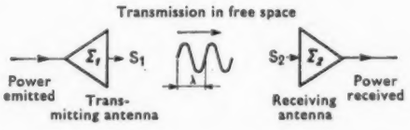


Fig. 1: Theoretical Diagram of a Wireless Link in Free Space. Σ_1 and Σ_2 represent the equivalent radiation surfaces of the transmission and receiving antennas respectively.

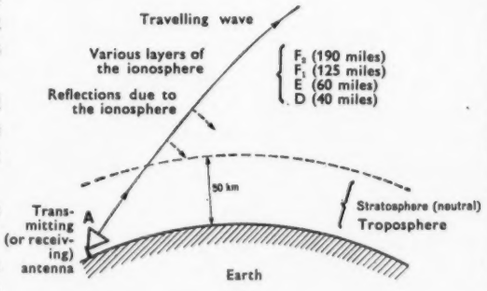
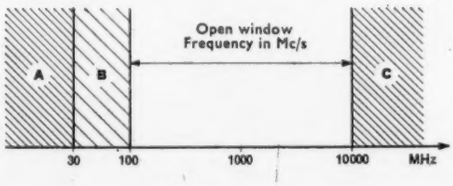


Fig. 2: The Atmospheric Screen

Fig. 3: Attenuation Caused by the Atmospheric Screen. A. frequency range barred by the ionosphere; B. frequency range in which random reflections by ionosphere are possible ("doubtful" range); C. frequency range barred by the troposphere.



We now turn to the principal causes of attenuation. In the lower altitude regions (i.e., under 12 miles), the air is of appreciable density and laden with water vapour; both the oxygen and water vapour give rise to absorption. Maximum attenuation due to oxygen is situated around a frequency of 60,000 Mc/s, whereas attenuation arising from water-vapour occurs to an appreciable extent only above 10,000 Mc/s, reaching its maximum at about 20,000 Mc/s. From these figures it follows that attenuation in the troposphere becomes appreciable above 10,000 Mc/s.

At higher altitudes (i.e. above 30 miles), where the density of the air is very low, ionization of the molecules of the air is brought about by solar radiation. This ionization acts as a true reflector screen for waves of relatively low frequency (short waves), against which it is an effective barrier. The upper frequency limit of waves reflected in this way is about 30 Mc/s. However, in order to be on the safe side and avoid the random reflections which occur from time to time, frequencies under 100 Mc/s are generally avoided for penetration of the ionosphere.

To sum up, it can be seen that the screen between the earth and a satellite is appreciably transparent over a vast range of frequencies, situated between 100 and 10,000 Mc/s, within which there is an open window to space (see *Fig. 3*), although certain factors must still be allowed for. These factors include rotation of the polarization field of the waves (through Faraday effect in the ionosphere in the presence of the earth's magnetic field); deviation of the transmission by reflection through the troposphere; and, lastly, apparent variation in the received frequency (doppler effect). These difficulties can, however, be overcome and rectified by adjusting the direction of the antennas and by adjusting the reception tuning.

Total receiver noise

In order to transmit information from the satellite, a modulation must of course be applied to the emitted signal. One important effect of this is that, instead of being made on a single frequency, f_o, transmission takes up a certain amount of bandwidth B on both sides of f_o, and it is accordingly imperative that the receiver used be capable of receiving the whole of this spread.

In view of the extensive possibilities of amplification provided by present-day techniques, the weakness of the signal received P_r would not be a problem if this signal was not accompanied by parasite noise, which develops a power of P_{noise}. A sufficiently high P_r/P_{noise} ratio must therefore be achieved if reception is to be satisfactory.

The two sources of parasitic noise are noise developed inside the receiver, arising from the receiver's own imperfections, and noise received by the antenna, coming fundamentally from space noise picked up within the antenna's directional lobe.

Instead of using a direct expression for noise level, it has become customary to represent this in terms of absolute equivalent temperature, T_{noise}; from this P_{noise} can be inferred by the classic equation for thermal noise produced by resistances, namely:

$$P_{noise} = k\, T_{noise}\, B \qquad (2)$$

(k being the Boltzmann constant).

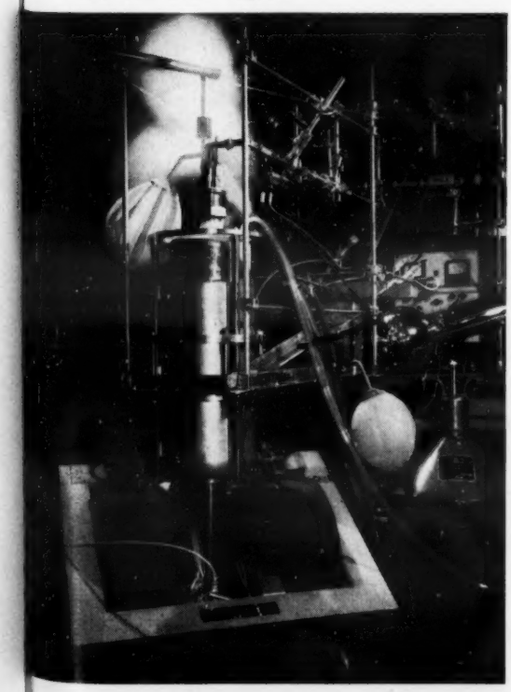
In this way both the noise of the receiver itself and that picked up by the antenna can be expressed, the sum of these two temperatures giving a total temperature from which total noise level can be found by an equation of type (2).

Noise temperatures give a good definition of the quality of reception. The fact that they are inversely proportional to B shows how important it is to reduce bandwidth in order to lower noise levels.

Parasitic noise received by the antenna (galactic noise)

Sources of radiation occur in space, where masses of low density gas emit parasitic radiations into the radio spectrum. Maximum emission is met with in the direction of our galaxy (the Milky Way). These radiations are received as thermal noise and as such can be assessed in terms of noise temperature. It has in this way been possible to draw space maps for various wavelengths, giving the temperature in various directions. This information is given graphically in figure 4, which shows space temperature as a function of frequency in respect of two extreme regions, which are (1) the noisiest zone (direction of our galaxy) and (2) a quiet zone. It will be seen that, when dealing with high performance links, we are compelled by the phenomenon of space noise to utilize frequencies between about 400 and 10,000 Mc/s.

Fig. 8 : Maser on a test-rig.



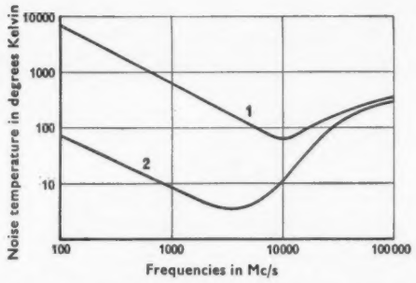


Fig. 4 : Space Noise (Approx) 1. Noisy zone (direction of our galaxy); 2. Quiet zone.

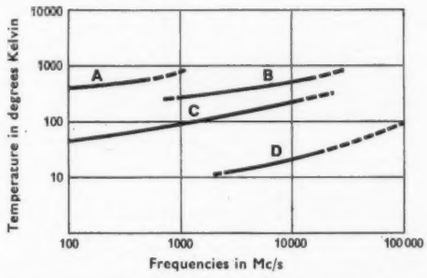


Fig. 5 : Noise Temperatures with Various Input Systems: A. triodes; B. travelling wave tube; C. parametric amplifier; D. maser. As can be seen above, the effectiveness of these systems varies in relation to pass band width, the travelling wave tube being the most satisfactory.

Noise from the receiver itself

The input circuits of any receiver are the seat of thermal noise, which limits its use in connection with weak signals. This noise level is expressed in absolute temperatures (degrees Kelvin) in accordance with formula 2.

Present-day techniques provide us with two methods of reducing receiver noise within the range of usable wavelengths. These are as follows:

(a) up to 1,000 Mc/s, triode valves can be used, and it is possible to arrive at a noise temperature of 900°K, and above 1,000 Mc/s the use of travelling wave tube amplifiers can be envisaged. In the years to come, one can count on achieving noise temperatures of 300°K.

(b) in addition to the classic methods, there are the two new systems using parametric amplifiers and masers.

The low noise amplification of parametric amplifiers is produced by a variation in the apparent value of one of the tuning elements of the input circuit by the action of an auxiliary source, known as the pump.

With masers, use is made of a similar increment of energy, but the energy exchanges are made at molecular level. The origin of these exchanges is a ruby crystal (alumina doped with chrome ions), which is subjected to a powerful magnetic field and dipped into liquid helium (2°K). The amplification energy is drawn from a " transition " between two energy states of the chrome ions in accordance with Planck's law (h = Planck constant).

$$\Delta W \text{ (energy increment)} = h\,fi$$
(fi being incident frequency).

The pump increases the upper level of energy by an auxiliary transition.

The noise temperatures which can be expected now or in the near future are $T_{noise} = 100°K$ by means of parametric amplifiers and $T_{noise} = 30°K$ by means of masers (on the highest frequencies in the band).

Ranges which can be achieved

To establish an order of magnitude for the ranges which can be achieved, we shall consider a link of 1,000 Mc/s, with a bandwidth of 10 c/s. It is necessary to confine oneself to narrow channels of this type (which assumes slow transmission of information) in order to achieve the ranges required.

We can now consider the satellite-to-earth link, the most difficult to achieve in view of the limited power available on the satellite. On the ground, we can have directional antenna giving a gain of 100,000 in relation to omni-directional radiation. An antenna of this type, which would be in the form of a parabola of 160 ft diameter, is well within the limits of practicability.

On the other hand, three levels are envisaged for the emitted power and aerial gain (in the satellite) and noise temperature (at the ground). The ranges obtainable for a noise received/parasitic noise ratio of 10 are shown in the following table:

	Level 1	*Level 2*	*Level 3*
Emitted power (satellite)	1W	10 W	100W
Antenna gain (satellite)	1	30	1,000
Noise temperature of receiver (ground)	1000° Kelvin	200° Kelvin	40° Kelvin
Space temperature	50° Kelvin	50° Kelvin	50° Kelvin
Approximate range (millions of miles)	4	125	4,000

From these examples it can be seen that, whereas level 1 takes care of communications over the distance between earth and moon (250,000 miles), level 2 is required for the

earth-sun range (93 million miles) and level 3 for reaching the limit of the solar system (the distance from the sun to Pluto being 3,670 million miles).

The nearest star is, however, 10,000 times more distant and for the time being beyond our possibilities. Ranges of this magnitude could be achieved by reducing the signal bandwidth B, but this obviously reduces the practical value of the experiment.

Looking at the links in the opposite direction, namely, earth-to-satellite, we see that the same antennas are in use and yield identical transmission efficiency. In the satellite (now the receiver), it is difficult to employ very low noise temperature systems owing to their complexity, and one is in general confined to the modest performances of level 1, as shown in the above table ($T = 1{,}000°$ Kelvin). The increase in noise level can however easily be compensated by an increase in emitted power (the factor in question is 10, and this presents no difficulty on the ground).

Use of satellites for earth communications

Long distance telephone links at present make use either of radio communication techniques on decametric waves or of submarine cables with submerged repeaters.

The disadvantage of the first method lies in the fact that it is subject to fluctuations in quality due to variations in reflection capacity in the ionosphere. The second procedure, whilst yielding results of high quality, involves major capital investments.

For a satellite intended to serve as an intermediate relay station in communication between two earth terminals which are very far apart and out of optical range, two alternative methods of relay are envisaged:

(a) passive relay, in which the satellite forwards the emitted signal to the receiver by means of reflection;

(b) active relay, in which a microwave link is placed on the satellite which therefore carries an aerial receiving station, an aerial transmitting station and an amplifying unit, all of which require duplication if the link is bilateral.

The attraction of the passive relay method is of course its simplicity. However, although the energy picked up is augmented at reception by an aerial gain represented by the equivalent surface of the satellite, there is no amplification of the energy picked up, which is moreover retransmitted omnidirectionally.

The active relay satellite, on the other hand, has the benefit of two aerial gains (G) (i.e. at transmission and at reception) plus the amplification of a repeater (A). Comparison between the equivalent gain in the passive system and the product representing the gain in the active system, namely $G_1 G_2 A$, leaves no doubt that there is a strong advantage in favour of the latter.

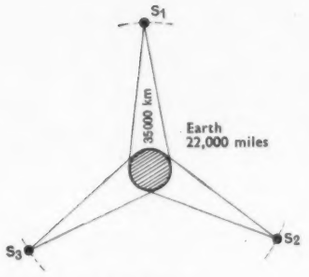


Fig. 6: Fixed Position Satellites.

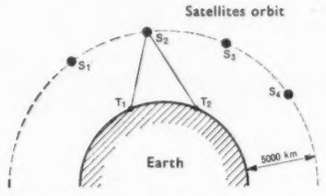


Fig. 7: Satellites Circling the Earth. S_1 etc. represent satellites. T_1 and T_2 represent two earth stations.

The passive satellite *Echo I* can serve as an example. This is a 100 ft diameter sphere, the equivalent surface of which can be very roughly estimated at 5,400 sq.ft. At the frequency of 1,000 Mc/s, the corresponding aerial gain will be of the order of 50,000. Taking the aerial gain (transmission and reception) for an active satellite at only 10^5, the total amplification factor already comes to

$$10 \times 10 \times 10^5 = 10^7$$

which is far more than with the passive satellite.

The bandwidths used in this type of communication (telephone, TV etc.) are much greater than the modest bandwidths in use for telemetry from very distant satellites. An increase in noise level therefore arises, but this disadvantage is offset by the much shorter distances to be contended with, which considerably improve transmission efficiency (see *formula 1*). A much better signal/noise ratio will be obtained than in the case of telemetry with distant satellites.

As regards the movements of the satellites themselves, two possibilities can be envisaged.

The first is that the satellite moves with the same angular speed as the rotation of the earth about its axis. Its height would then be around 22,000 miles, and three satellites situated over the equator at this altitude would be enough to ensure relay between all points on the earth's surface *(Fig. 6)*. These satellites would appear stationary in relation to the earth.

The second possibility is for the satellite's orbit to be at an appreciably lower level, under 3,000 miles for example. The satellite then circles the earth in a matter of a few hours, as in the case of low orbit satellites launched to date.

For a system of this kind, it would be necessary to launch a chain of satellites spaced at regular intervals, in order that one is always available to two earth stations. It should be noted that one satellite can be used for a relatively small period only, say a quarter of an hour, and an appreciable number of satellites is therefore required (see *Fig. 7*).

In the second method, the essential problem is that of aiming the antennas on to their targets. On the ground this is a question of continuously directing the antenna toward the satellite, while on the satellite, in the case of an active system, the antennas must also be maintained in the requisite directions. This aiming must be carried out automatically and continuously by electronic control.

Technical problems

It is possible only to catalogue briefly the numerous problems which arise in connection with telecommunications equipment for satellites.

Power supply must be provided by accumulators, which are recharged by solar cells. The long periods of exposure to sunlight which occur at high altitude make this system satisfactory.

The high-frequency detector circuits of the receiver require special attention. The doppler effect already mentioned results in a displacement of the mean transmission frequency considerably beyond the narrow bandwidth used for telemetry. In order not to lose the signal, it is necessary to design the receivers with a sufficiently broad high-frequency bandwidth. To retain the advantage of lower noise obtained with the narrow band, this reduction must be carried out after the detector stage, which will be of a special type.

All available technical resources are needed for the modulation procedures (frequency and pulse modulation) in order to achieve the necessary time division multiplexing of the information transmitted (telemetry or telephone) in accordance with the principles of the theory of information.

In some cases the information will be in varying forms, such as telephotos or messages, and it is essential to provide the appropriate recording apparatus.

Lastly, the components must be able to stand up to the exacting temperatures, vibration and acceleration conditions in space vehicles.

*

The problems of telecommunications with and via satellites, which have been dealt with in this article, offer wide fields of research, and this will inevitably bring about enormous progress in radio engineering, hitherto confined to applications in the neighbourhood of the earth's surface only. Improved terrestrials communications will be a product of these researches.

Book Reviews

Die besonderen meteorologischen Bedingungen für den Strahlluftverkehr. — By Professor Edgar Rössger. — No. 54 of the technical and economic reports of the North Rhine-Westphalia Ministry of Economics and Transport, edited by Professor Leo Brandt, 1960 (German; 153 pages with illustrations; printed typescript).

As emphasized at the beginning of the report, the aim has not been to offer new solutions to the meteorological problems which are of such importance to both civil and military jet aircraft; the intention is rather to give an analysis of the structure of meteorological phenomena on the basis of the vast amount of material already at hand, thereby laying the foundations for a reliable assessment of their effects on air transport. Accordingly, the report contains no new material, but an excellent summary of the already well-known features of high-altitude turbulence and jet streams and a chapter on their effects on air transport. The report supplements Report No. 51, which appeared in the same series ("Auswirkungen des Einsatzes strahlgetriebener Flugzeuge im Luftverkehr," also by Professor Rössger).

Eb.

Principles and Practice of Aircraft Electrical Engineering. — By H. Zeffert. — George Newnes Limited, London, 1960 (English; 726 pages with numerous illustrations; price 90/-).

The author of this book is Chief Electrical Engineer at Vickers Armstrongs (Aircraft) Ltd., and has been active in his field for over 25 years. Under his direction the electrical systems of a number of Vickers aircraft were developed, including those for the *Viking*, *Viscount*, *Vanguard*, VC.10 and some military aircraft. It is therefore not surprising that the present work is written from a thorough knowledge of the subject. It contains valuable information for design engineers, technicians and students, ranging from aircraft power supplies, instrumentation, radio and navigation systems to the electrical equipment for aircraft galleys. In order to keep the size of his book within reasonable limits, the author has had to restrict himself to a description of basic techniques in each chapter, abandoning as far as possible electrotechnical and mathematical formulae. The omission of such details, which are often considered as "padding," makes the book more concise and readable, and a comprehensive index makes it an invaluable work of reference.

Eb.

Das Bildbuch der Weltraumfahrt. — Edited by Heinz Gartmann. Umschau Verlag, Frankfurt am Main, 1960 (German; 48 pages of text; 96 pages of pictures with 145 illustrations; cardboard bound; price DM 16.80).

Did you know that earth satellites are worth more than their weight in gold? Heinz Gartmann, the internationally famed astronautical writer, who died last year, tells us their cost and many other interesting facts in this picture-book of astronautics. As in all his books, Gartmann has succeeded in revealing the wonders of this branch of science to the layman, complementing his concise introductory text by a series of excellent illustrations. Beginning with a brief survey of the subject, he goes on to describe earth satellites and space probes, discusses the plans of the astronautical industry and touches on the problems confronting man in space. The picture section offers a variety of photographs and drawings, ranging from the earliest beginnings of rocketry through the experiments of latter years—satellites, boosters, motors, instrumentation, equipment—to the visions of serious-minded scientists and technicians.

De.

Die deutschen Flugzeuge 1933-1945. Deutschlands Luftfahrt-Entwicklungen bis zum Ende des zweiten Weltkrieges. — Karlheinz Kens and Heinz J. Nowarra. — J. F. Lehmann Verlag, Munich, 1961 (German; 816 pages, 693 illustrations; cloth-bound; price DM 68).

The two authors spent seven years collecting the material for this work which, in the end, turned out twice the size originally planned. Their object was to present as complete a picture as possible of German aircraft planned and built between 1933 and 1945. Although there is a concluding remark to the effect that new material is expected to come in after publication, this volume constitutes a catalogue which should be unique in German technical literature. In addition to detailed descriptions of production models, research aircraft and prototypes, this volume covers practically all planned models which could have been built at the time but which in fact never reached the production stage owing to the war. Rockets, missiles, aero engines and aircraft weapons of the time are also covered, and the comprehensive illustrations at the end of the book show many hitherto unpublished special versions of normal production types and jet aircraft developments of the time. This book, with its impartial approach, should prove a veritable mine of information for all interested in aeronautics, especially in developments during this important period.

Eb.

Statische Längsstabilität und Längssteuerung. — Volume 11 of the Schriftenreihe zur Berechnung von Flugzeugen, edited by Dr. W. Just. — Flugtechnik, Stuttgart, 1959 (German; 147 pages, 45 illustrations; price DM 15.40).

The author of this book, who is Director of the Technical and Scientific Department of the Deutsche Studiengemeinschaft Hubschrauber and tutor at the Stuttgart Institute of Technology, is well known in specialist circles from a number of publications. According to the scheme given in volume 11 of his series on aircraft stress analysis, the series will ultimately comprise 27 volumes on aircraft performance, flight qualities, aerodynamics, measurements, load capacity, stress aerodynamics and statics. Volume 11 is the first of the section on flight qualities, which will consist of five volumes, and deals with the manifold problems of static pitch stability and pitch control. In the first chapter the author defines flight qualities (controllability, trimmability, shifts in load, instability). The following chapters deal with the theory of the centre of pressures and wing pitching moments and a simplified theory of static pitch stability and controllability. These are followed by chapters on the theory of static pitch stability with propellers in motion, at high speeds and at maximum lift coefficient, all-wing aircraft, the measurement of static pitch stability and the equilibrium of moments on take-off and landing.

Eb.

Jane's All the World's Aircraft 1960/61. — Compiled and edited by John W. R. Taylor. Sampson Low, Marston & Company Ltd., London, 1960 (English; 574 pages; 1,176 illustrations; price £5.5.0).

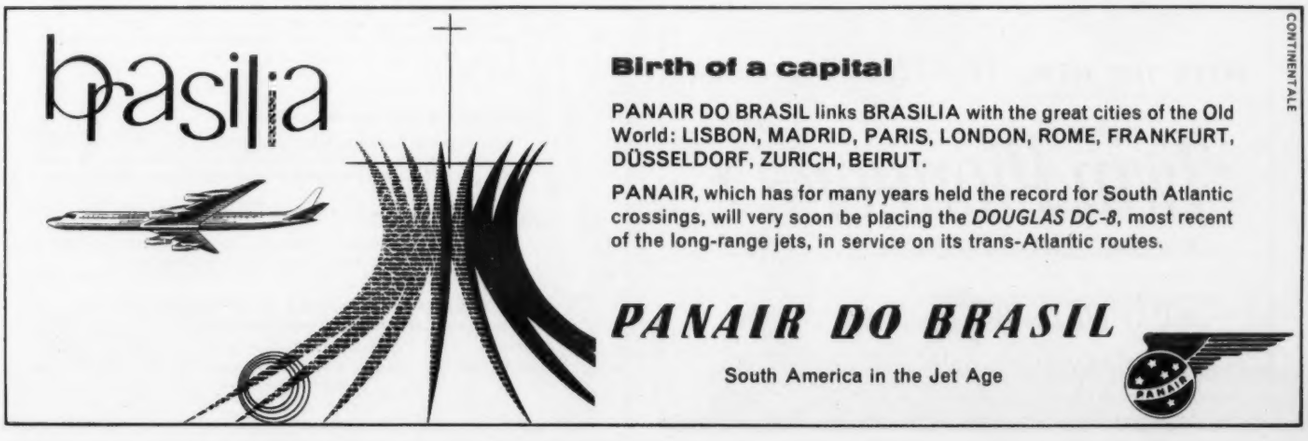
Edited for the first time by John W. R. Taylor, so far the leading collaborator of Leonard Bridgeman, the new Jane's presents the same familiar picture. Meticulous down to the last detail, it contains 413 pages of descriptions, photographs and drawings of new aircraft and those already in production, including the *Dyna-Soar* and *Mercury* manned space vehicles. The unmanned aircraft, rockets and guided missiles section contains 61 pages, eleven more than in the previous year. More space has also been devoted to airships, but the engine section has shrunk from 98 to 92 pages. The number of "home-made" aircraft in this year's volume is impressive; and the number of sailplanes and ground effects machines has increased. Of the 1,176 illustrations, no fewer than 702 are new. Countries appearing for the first time, or reappearing after a gap of some years, are New Zealand, Norway and South Africa. In response to many requests, the new Jane's also contains an extract from the Fédération Aéronautique Internationale's record list. The present edition, too, will win new friends for this indispensable handbook of aviation.

De.

Aircraft Engines of the World 1960/61. — By Paul H. Wilkinson. — Paul H. Wilkinson, 734, 15th Street N.W., Washington 5, D.C.; 1960 (English, 288 pages).

Comprehensive and authoritative as ever, the eighteenth edition of this year-book, which has become a standard work of reference for aircraft engines all over the world, gives detailed descriptions of operational aircraft engines in the West and (as far as they are known) the East: 143 gas turbines; 77 of the piston engines which are still in service in large numbers today; and rocket motors for primary and auxiliary propulsion. Of the greatest value is a section on engine accessories, included for the first time this year. An index of the engine types in use between 1953 and 1959 enables information to be rapidly found in earlier editions, and the detailed conversion tables are an invaluable aid. Once again Wilkinson's reference book will take its accustomed place on the shelves of every aviation library.

Ba.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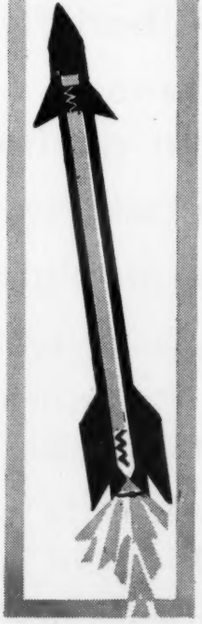

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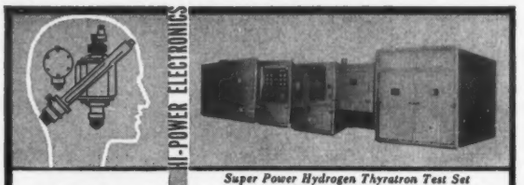

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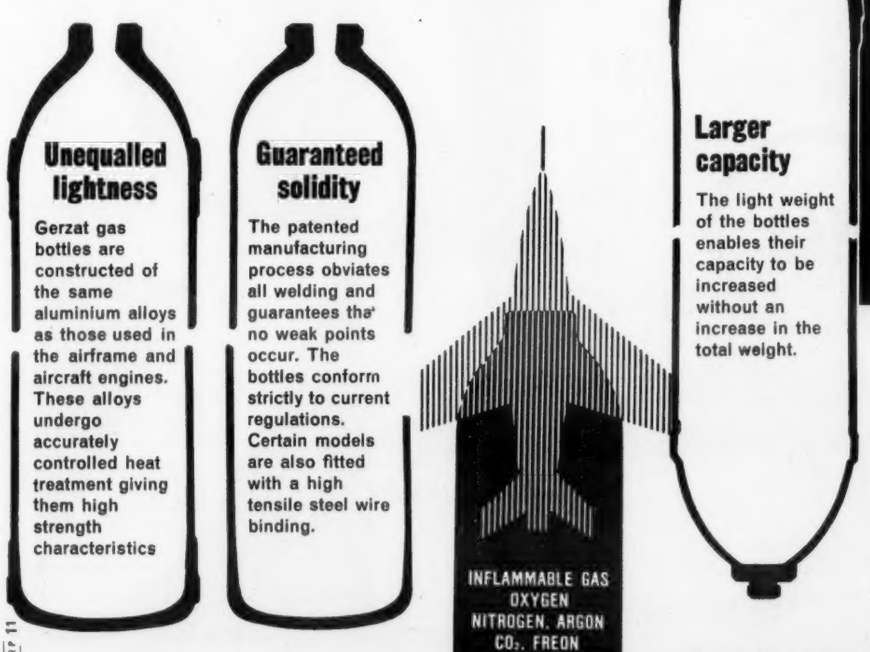

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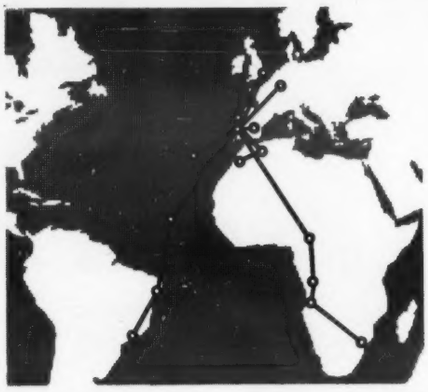

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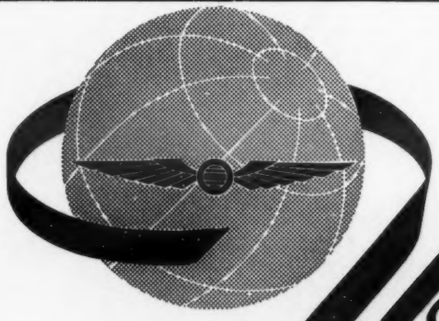

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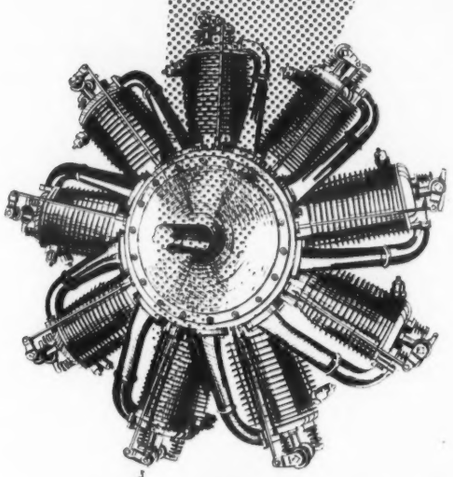

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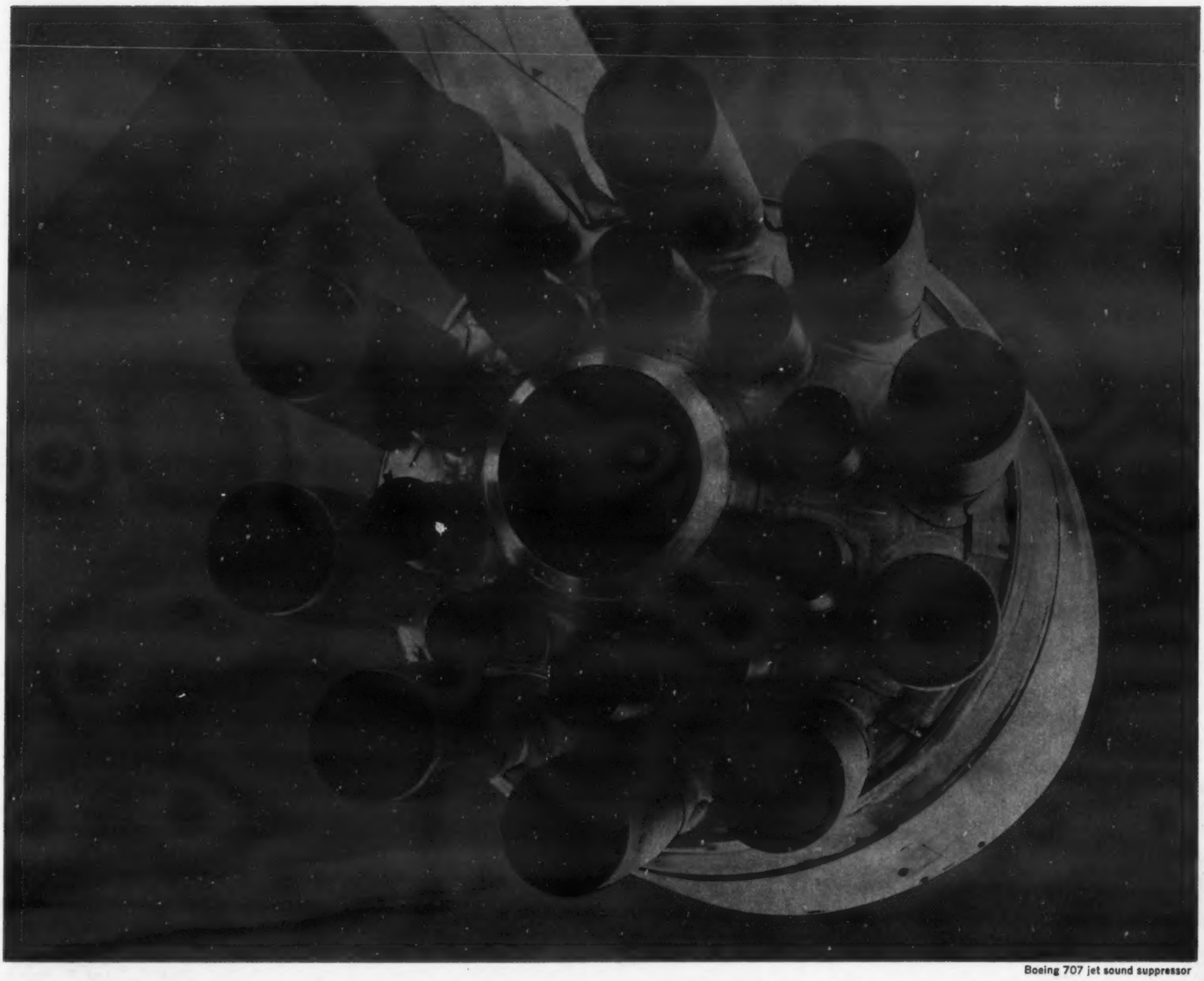

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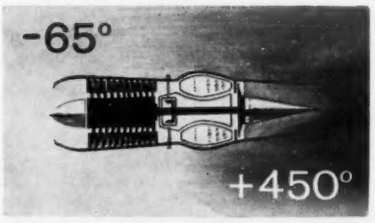

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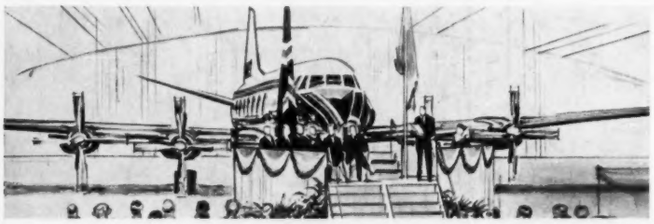

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